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Effects of short-, medium- and long-term resistance exercise training on cardio-metabolic health outcomes in adults: systematic review with meta-analysis

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ABSTRACT

Objective: To examine the effects of short-, medium- and long-term resistance exercise training (RET) on measures of cardio-metabolic health in adults.

Design: Intervention systematic review

Data sources: MEDLINE and Cochrane Library databases were searched from inception to February 2018. The search strategy included the keywords: resistance exercise, strength training, randomised controlled trial.

Eligibility criteria for selecting studies: RCTs published in English comparing RET >2 weeks in duration with a non-exercising control or usual care group. Participants were non-athletic and aged ≥18 years.

Results: A total of 173 trials were included. Medium- and long-term RET reduced systolic blood pressure (-4.02 [95% CI: -5.92, -2.11], mmHg P < 0.0001 and -5.08 [-10.04, -0.13] mmHg, P = 0.04, respectively) and diastolic blood pressure (-1.73 [-2.88, -0.57] mmHg, P = 0.003 and -4.93 [-8.58, -1.28] mmHg, P = 0.008, respectively) versus control. Medium-term RET elicited reductions in fasted insulin and insulin resistance (-0.59 [-0.97, -0.21] µU/ml, P = 0.002 and -1.22 [-2.29, -0.15] µU/ml, P = 0.02, respectively). The effects were greater in those with elevated cardio-metabolic risk or disease compared to younger healthy adults. The quality of evidence was low or very low for all outcomes. There was limited evidence of adverse events.

Conclusions: RET may be effective for inducing improvements in cardio-metabolic health outcomes in healthy adults and those with an adverse cardio-metabolic risk profile.

KEYWORDS: cardiovascular, exercise training, systematic review, strength training

INTRODUCTION

Cardiovascular disease is a substantial human and economic burden, responsible for 17.7 million deaths globally in 2015 [1]. The positive impact of regular moderate to vigorous intensity aerobic exercise (e.g. brisk walking, jogging, cycling) on cardio-metabolic health, including improvements in cardiopulmonary exercise capacity, blood pressure, glycaemic control, hypercholesterolemia and vascular endothelial function [2, 3], is well-documented and recognised in current UK and global physical activity recommendations [4, 5]. However, while the health benefits of regular resistance exercise training (RET) in relation to maintaining skeletal muscle size and strength are also recognised in current physical activity recommendations, the role of RET in enhancing cardio-metabolic health is less well defined.

RET is characterised by muscular activities working against an external load and may be easier than aerobic exercise to implement and sustain in the home environment as it offers an alternative way to exercise for older adults who have limited space or access to equipment and time availability [6-8]. Most studies of RET have focused on changes in skeletal muscle size and strength, with few investigating cardio-metabolic health effects as primary outcomes although several have reported cardio-metabolic variables as secondary outcomes [9, 6, 10].

There is preliminary evidence that RET may positively alter blood lipid profile, body composition, systolic blood pressure [11-13], circulating inflammatory markers and cardiopulmonary exercise capacity [14, 15, 2]. RET may also generate longer-lasting improvements in body fat, fasted insulin, lipid profile and systolic blood pressure than aerobic exercise [16, 17]. Finally, RET may have an important role in attenuating age-related physiological changes such as increases in systolic blood pressure and arterial stiffness, and the reduction of skeletal muscle mass (with associated changes in systemic physiology) [18, 3].

Aside from the lack of RET intervention studies with a primary focus on cardio-metabolic health outcomes, interpreting the impact of RET on cardio-metabolic health is constrained by heterogeneity of methodology, including the duration of interventions and populations. High-quality systematic reviews and meta-analyses can help to overcome these challenges, while accounting for bias and heterogeneity, by providing more precise estimates of effect size changes. The aim of this systematic review was to assess the effects of short-, medium- and long-term RET programmes compared to control or usual care on cardio-metabolic health outcomes in adults.

METHODS

The preferred reporting items for systematic review and meta-analyses (PRISMA) guidelines were followed [19] when conducting and reporting this prospectively registered systematic review (PROSPERO ID CRD42016037946).

Eligibility criteria

We included randomised controlled trials (RCTs) published in English that compared any RET programme alone to a non-exercising control or usual care group. Participants must have been aged ≥ 18 years, non-athletic [20], and recruited to a RET programme (e.g. elastic resistance band, weight machines, etc.) of at least 2 weeks duration, irrespective of intensity or frequency that was conducted in any setting (e.g. home, hospital). We included studies where isometric RET with whole body vibration was used. We excluded studies where RET interventions were combined with other lifestyle components or exercise modes (e.g. aerobic exercise, diet, etc.) to isolate the effects of RET. Studies that included at least one of the following cardio-metabolic health outcomes or clinical end-points were eligible: $\dot{V}O_2max$; flow-mediated dilatation; C-reactive protein; total cholesterol; high-density lipoprotein cholesterol; low-density lipoprotein cholesterol; triglycerides; fasted glucose; fasted insulin; insulin resistance (HOMA-IR); resting blood pressure; mean arterial pressure; resting heart rate; cardiovascular mortality; all-cause mortality; non-fatal end-points (e.g. myocardial infarction, coronary artery bypass grafting; percutaneous transluminal coronary angioplasty; angina or angiographically-defined coronary heart disease; stroke; carotid endarterectomy; peripheral arterial disease.

Search strategy

The MEDLINE Ovid and Cochrane Library databases were searched from inception to February 2018. The search strategy keywords and MeSH terms used included: progressive resistance, strength training, exercise and randomised controlled trial. Details of the full search strategy can be found in supplementary table 1. Reference lists of all relevant systematic reviews identified were searched for additional studies.

All searches were conducted by the same author (RA), with search results collated using EndNote software (Thomson Reuters, New York), and duplicates removed.

The first 10% of titles and abstracts were screened independently by two reviewers (RA and GT) and, due to good agreement, the remaining texts were screened by one reviewer only (RA, GT, JS or LL) [21]. Screening of full-texts was performed by two independent reviewers (RA and GT) with disagreements resolved through consensus or a third reviewer being consulted (JS).

Data extraction

Two authors (RA and SG) independently extracted data using Microsoft Excel. Any disagreements were resolved via consensus. When more than one publication was apparent for the same trial, data were collated (supplementary table 2). We extracted study design, participant demographics, intervention details and means and standard deviations for all outcomes. When necessary, published protocols and trial registries were searched for further methodological detail and risk of bias assessment. If there was insufficient information the authors (n = 40) were contacted via email. Resting blood pressure was expressed in millimetres of mercury (mmHg); resting heart rate in beats per minute (bpm), $\dot{V}O_2max$ relative to body mass (ml/kg/min), flow-mediated dilatation as percentage, fasted insulin in micro units per millilitre (μU/ml), C-reactive protein in milligrams per litre (mg/L) and glucose, lipid profile and HOMA-IR in milligrams per decilitre (mg/dL). Adverse events were also extracted.

Risk of bias

Risk of bias was assessed by two authors independently (RA and SG) using the Cochrane Risk of Bias tool [22]. Any disagreements were resolved through consensus. We judged risk of bias on the study level as ‘low’, ‘unclear’ or ‘high’ risk [23]. We used funnel plots to assess publication bias when there were more than 10 studies contributing data for an analysis [24, 23]. For all outcomes we conducted sensitivity analyses. For the sensitivity analyses, we excluded studies that were judged as being at unclear risk of bias on a majority of domains of the Cochrane tool, or where at least 2 domains of the Cochrane tool were judged as being at high risk of bias, and ran the meta-analysis again.

Data synthesis

Meta-analyses were undertaken using Review Manager (RevMan 5.3; Cochrane Collaboration, Oxford, UK) when more than two studies reported on the same outcome. In the pooled analysis of studies by duration, outcome data were organised into short-term (≤6 weeks), medium-term (7-23 weeks) and long-term (≥24 weeks) arbitrary categories. Where units of measurement could not be converted, standardised mean differences (SMD) were used. Data are presented as mean and 95% confidence intervals. The I^2 statistic was used to quantify statistical heterogeneity as follows: 0-40%: might not be important, 30-60%: moderate heterogeneity, 50-90%: substantial heterogeneity, 75-100%: considerable heterogeneity [23]. Fixed-effects model was used for analysis however, if statistical heterogeneity was noted (I^2 >40%), meta-analysis was performed using a random-effects model. The GRADE approach was used to assess the strength of evidence. Studies were downgraded if there were issues with risk of bias, consistency, precision or directness of the outcomes. The reasons for downgrading the evidence are outlined in Table 1.

Table 1. Criteria for downgrading the quality of outcomes using the GRADE approach.

	Reason to downgrade the level of evidence
Risk of bias	• Majority of studies rated as being at unclear risk of bias • Outcome includes studies that have been rated as being at high risk of bias in 2 or more categories
Inconsistency	• Large heterogeneity based on the similarity of point estimates, statistical heterogeneity and $I^2 \geq 50\%$
Imprecision	• Large confidence intervals when data are presented as standardised mean difference • Substantial heterogeneity ($I^2 \geq 50\%$) • If a recommendation or clinical course of action would differ if the upper versus the lower boundary of the confidence interval represented the truth • Sample size < 400 within the meta-analysis for each variable
Indirectness	• Use of surrogate outcomes
Publication bias	• Asymmetric funnel plot

Where multiple RET groups were compared to a single control group, data for the intervention most similar to traditional RET was used for the analysis. After the initial analysis, sub-group analyses were conducted to explore sources of heterogeneity by dividing studies into three categories: healthy young adults aged 18-40 years; healthy older adults ≥ 41 years old; older adults ≥ 41 years old with elevated cardio-metabolic risk or established disease (defined as any elevated blood marker above normal levels or overweight, obese or hypertensive participants). Adverse events were synthesised descriptively.

RESULTS

A total of 19,040 records were retrieved from database searches, of which 5,669 records were duplicates. A further 11,696 were then eliminated following screening of titles and abstracts (Figure 1). Sixty-three potentially relevant papers were identified from screening of systematic review reference lists (Figure 1). After full-text screening of 1,738 articles, 194 manuscripts from 173 RCTs were included in this review (Figure 1). Participants were individually randomised in all included trials (i.e. there were no cluster RCTs).

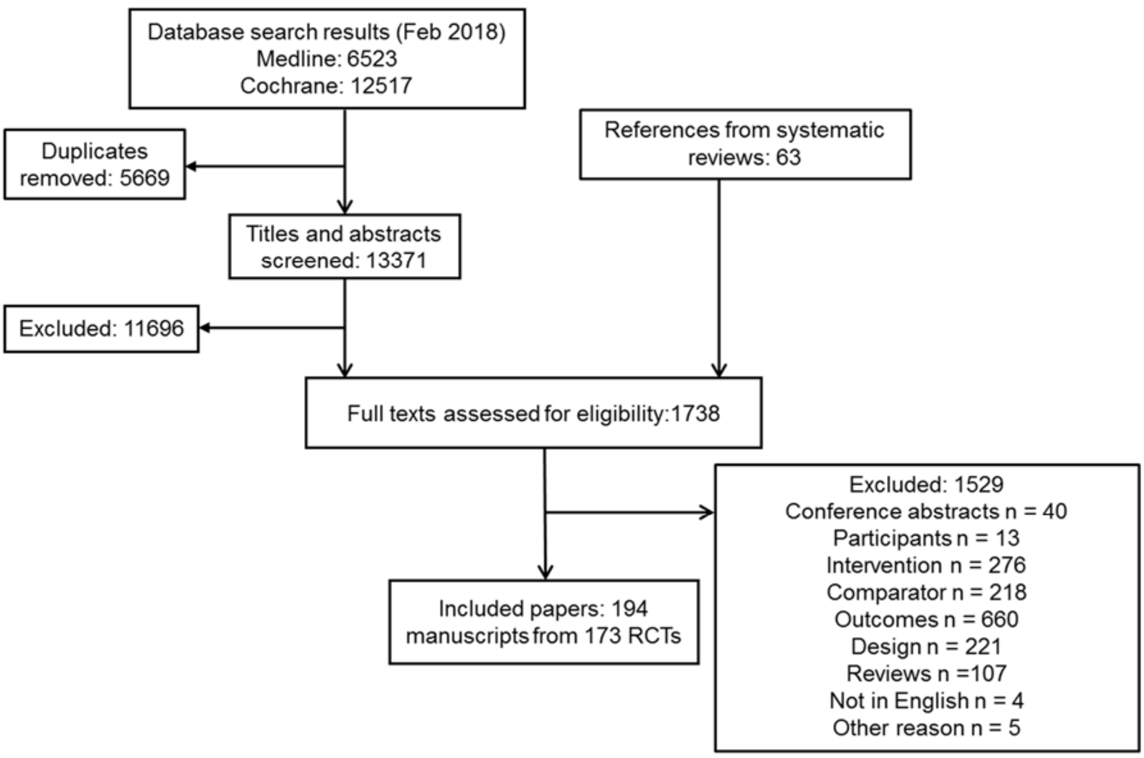

Figure 1. PRISMA flow diagram

Study characteristics

The 173 RCTs comprised 6,169 participants (2,840 control and 3,329 RET participants), with sample sizes of 5-77 per group and 13-150 per study. One hundred studies involved healthy individuals and 73 studies involved clinical populations. All included studies were published between 1978 and February 2018. Summary details of the included trials and populations are presented in supplementary table 2 and 3 respectively.

RET programmes mainly used weight machines (n = 90 studies; 52%), a mix of free weights, bodyweight and machine exercises (n = 43 studies; 25%), elastic resistance bands (n = 13 studies; 8%), circuit exercises (n = 12 studies; 7%), free weights (n = 10 studies; 6%), ankle/leg weights (n = 2 studies; 1%), isometric hand grip (n = 2 studies; 1%) and isometric exercise with whole body vibration (n = 1 study).

The majority of interventions were supervised by an exercise professional (n = 105 studies; 61%). One study reported data from an unsupervised intervention, and 13 (8%) used a combination of supervised and unsupervised programmes. Fifty-four studies (31%) did not report the level of supervision.

The duration of the intervention varied from ≤ 6 weeks (n = 13), 7-23 weeks (n = 129) and ≥ 24 weeks (n = 31). The most common frequency of training was 3 sessions per week (n = 110), followed by 2 sessions per week (n = 36), though some studies required participants to complete the programme in 1, 4 or 5 sessions per week (n = 1, n = 7 and n = 5, respectively). The remaining studies stipulated either two-three sessions per week (n = 8), three-four sessions per week (n = 1) or did not report the frequency (n = 5).

In the majority of studies, control participants were instructed to continue with their habitual activity (n = 115/173) or were allocated to usual care (n = 15). Three studies provided lifestyle advice to the control group and discussion about physical activity levels, but no structured/supervised exercise (n = 3). Forty studies did not report the requirements of the control group. The included studies did not report any clinical end-points. A summary of the quality of evidence, based on risk of bias, study design, confidence intervals and variability in results, has been collated using the GRADE approach (Table 2).

Table 2. GRADE summary of findings.

Outcome		Anticipated absolute effects (95% CI)		Number of participants (RCTs)	Certainty
		Risk with control group	Risk with resistance exercise training		
Cardiovascular morbidity/mortality		Could not be calculated due to lack of reporting.			
Systolic blood pressure (mmHg)	*ST*	**115.45** mmHg	MD **3.17 mmHg lower** (6.95 lower to 0.6 higher)	116 (4 RCTs)	⊕○○○ VERY LOW [a,b,c]
	MT	**122.8** mmHg	MD **4.02 mmHg lower** (5.92 lower to 2.11 lower)	1456 (46 RCTs)	⊕○○○ VERY LOW [a,c,d]
	LT	**131.6** mmHg	MD **4.88 mmHg lower** (10.55 lower to 0.78 higher)	346 (7 RCTs)	⊕⊕○○ LOW [a,c]
Mean arterial pressure (mmHg)	*ST*	**86.5** mmHg	MD **3.31 mmHg lower** (6.86 lower to 0.78 higher)	67 (3 RCTs)	⊕○○○ VERY LOW [a,b,c,d]
	MT	**79.6** mmHg	MD **1.57 mmHg lower** (4.6 lower to 1.46 higher)	238 (10 RCTs)	⊕○○○ VERY LOW [a,b,c,d]
Diastolic blood pressure (mmHg)	*ST*	**65.2** mmHg	MD **1.44 mmHg lower** (4.73 lower to 1.86 higher)	52 (3 RCTs)	⊕○○○ VERY LOW [a,b,c]
	MT	**74.3** mmHg	MD **1.73 mmHg lower** (2.88 lower to 0.57 lower)	1418 (45 RCTs)	⊕⊕○○ LOW [a,c]
	LT	**76** mmHg	MD **4.93 mmHg lower** (8.58 lower to 1.28 lower)	346 (7 RCTs)	⊕○○○ VERY LOW [a,b,c,d]
Resting heart rate (bpm)	*ST*	**72** bpm	MD **2.66 bpm lower** (7.55 lower to 2.23 higher)	30 (2 RCTs)	⊕○○○ VERY LOW [a,b,c,d]
	MT	**67.8** bpm	MD **0.35 bpm higher** (1.44 lower to 2.13 higher)	977 (35 RCTs)	⊕○○○ VERY LOW [a,c,d]
	LT	**57.4** bpm	MD **0.48 bpm lower** (3.12 lower to 2.17 higher)	142 (5 RCTs)	⊕○○○ VERY LOW [a,b,c,e]
Flow Mediated Dilatation (%)		**7.8** %	MD **1.69 % higher** (0.97 higher to 2.41 higher)	138 (6 RCTs)	⊕⊕○○ LOW [a,c]
Total Cholesterol (mg/dL)	*ST*	**179.3** mg/dL	MD 5.55 **mg/dL lower** (9.62 lower to 5.47 higher)	146 (3 RCTs)	⊕○○○ VERY LOW [a,c,e]
	MT	**180.9** mg/dL	MD **0.57 mg/dL higher** (5.63 lower to 6.77 higher)	882 (32 RCTs)	⊕○○○ VERY LOW [a,c,d]
	LT	**198.6** mg/dL	MD **8.71 mg/dL lower** (30.83 lower to 13.4 higher)	212 (8 RCTs)	⊕○○○ VERY LOW [a,b,c,d,e]
High-density lipoprotein cholesterol (mg/dL)	*ST*	**53.8** mg/dL	MD **0.82 mg/dL higher** (5.4 lower to 7.03 higher)	146 (3 RCTs)	⊕○○○ VERY LOW [a,b,c,e]
	MT	**53.3** mg/dL	MD **2.35 mg/dL higher** (0.66 lower to 5.35 higher)	1114 (38 RCTs)	⊕○○○ VERY LOW [a,c,d]
	LT	**53.5** mg/dL	MD **2.79 mg/dL higher** (0.69 lower to 6.82 higher)	339 (9 RCTs)	⊕⊕○○ LOW [a,c]
Low-density lipoprotein cholesterol (mg/dL)	*ST*	**105.6** mg/dL	MD **5.1 mg/dL lower** (11.09 lower to 0.9 higher)	146 (3 RCTs)	⊕○○○ VERY LOW [a,b,c,e]
	MT	**110.1** mg/dL	MD **2.86 mg/dL lower** (8.77 lower to 3.05 higher)	1000 (31 RCTs)	⊕○○○ VERY LOW [a,c,d]
	LT	**118.3** mg/dL	MD **3.69 mg/dL lower** (10.99 lower to 3.6 higher)	265 (6 RCTs)	⊕○○○ VERY LOW [a,b,c]
Triglycerides (mg/dL)	*ST*	**115.2** mg/dL	MD **3.63 mg/dL lower** (17.45 lower to 10.2 higher)	146 (3 RCTs)	⊕○○○ VERY LOW [a,b,c,e]
	MT	**91.8** mg/dL	MD **3.99 mg/dL lower** (8.78 lower to 0.8 higher)	1165 (37 RCTs)	⊕○○○ VERY LOW [a,c,d]
	LT	**102.7** mg/dL	MD **2.82 mg/dL lower** (14.98 lower to 9.33 higher)	265 (6 RCTs)	⊕○○○ VERY LOW [a,b,c]

Table 2 cont.

Fasted insulin (μU/ml)	*MT*	**16.2** μU/ml	MD **1.11 μU/ml lower** (1.74 lower to 0.49 lower)	590 (20 RCTs)	⨁◯◯◯ VERY LOW [a,c,d]
	LT	**13.8** μU/ml	MD **0.4 μU/ml lower** (1.62 lower to 0.81 higher)	179 (4 RCTs)	⨁◯◯◯ VERY LOW [a,b,c,d]
HOMA-IR	*MT*	**6.1**	MD **1.22 lower** (2.29 lower to 0.15 lower)	184 (9 RCTs)	⨁◯◯◯ VERY LOW [a,b,c,d]
	LT	**3.8**	MD **0.18 lower** (0.64 lower to 0.27 higher)	71 (3 RCTs)	⨁◯◯◯ VERY LOW [a,b,c]
Fasted glucose (mg/dL)	*ST*	**87.3** mg/dL	MD **3.39 mg/dL lower** (6.9 lower to 0.11 higher)	122 (2 RCTs)	⨁◯◯◯ VERY LOW [a,b,c]
	MT	**100.7** mg/dL	MD **2.39 mg/dL lower** (4.47 lower to 0.31 lower)	984 (34 RCTs)	⨁◯◯◯ VERY LOW [a,c,d]
	LT	**92.3** mg/dL	MD **0.7 mg/dL lower** (2.8 lower to 2.67 higher)	271 (7 RCTs)	⨁◯◯◯ VERY LOW [a,b,c,d]
C-reactive protein (mg/L)	*ST*	**2.4** mg/L	MD **0.13 mg/L lower** (0.25 lower to 0.01 lower)	82 (2 RCTs)	⨁◯◯◯ VERY LOW [a,b,c,e]
	MT	**3.2** mg/L	MD **0.11 mg/L lower** (0.6 lower to 0.38 higher)	394 (12 RCTs)	⨁◯◯◯ VERY LOW [a,c,d]
Aerobic capacity (ml/kg/min)	*ST*	**28.6** ml/kg/min	MD **2.07 ml/kg/min higher** (0.75 higher to 3.39 higher)	308 (9 RCTs)	⨁◯◯◯ VERY LOW [a,b,c]
	MT	**28.9** ml/kg/min	MD **1.07 ml/kg/min higher** (0.38 higher to 1.76 higher)	1454 (48 RCTs)	⨁◯◯◯ VERY LOW [a,c,d,e]
	LT	**23** ml/kg/min	MD **1.22 ml/kg/min higher** (0.44 higher to 2.0 higher)	399 (11 RCTs)	⨁◯◯◯ VERY LOW [a,c,e]

CI - Confidence interval; RCTs – randomised controlled trials; MD – mean difference; ST – short term; MT – medium term; LT – long term
a – Downgraded due to being a surrogate outcome.
b – Downgraded due to potential for a recommendation or clinical course of action differing if the upper versus the lower boundary of the CI represented the truth and/or a sample size <400.
c – Publication bias suspected after inspection of funnel plots.
d – Inconsistent due to high heterogeneity, non-overlap of CI and/or markedly dissimilar point estimates.
e – Risk of bias was judged to be high.

Risk of bias

Figure 2 shows a summary of the risk of bias decisions made per category for the included studies. Supplementary table 4 describes risk of bias for each study in detail.

Selection bias

An acceptable method of random sequence generation (i.e. computer generated) was used in 36 studies, 8 studies were judged as being at high risk of bias and the remaining 129 studies were judged as being at unclear risk due to insufficient information to determine randomisation methods. The majority of studies (n = 156) did not report allocation concealment and were judged as unclear. Fourteen studies were judged as being at low risk of bias as allocation was blinded. In 3 studies, the researchers were not blinded to the allocation process and we judged these studies as being at high risk of bias.

Performance and detection bias

All trials were at high risk of performance bias (i.e. blinding of participants to the intervention and outcomes). Lack of investigator blinding could have influenced measures of resting blood pressure and flow-mediated dilatation but is more likely to have had an impact on the motivation provided to participants during $\dot{V}O_2max$ tests. The majority of studies (n = 144) were rated as unclear for detection bias (i.e. blinding of outcome assessor) due to insufficient information provided in the studies. Two studies were at high risk of detection bias, with the remaining 27 studies at low risk.

Attrition bias

The majority (n = 122) of studies were judged as being at low risk for incomplete outcome data. A further 37 studies were rated as unclear risk due to attrition rates >20% in one of the study groups (i.e. control or RET). Few studies were rated as high risk (14) due to high dropout rates or some participants being excluded from the analysis.

Reporting bias

The majority (n = 166) of studies were rated as low risk for selective reporting bias. A further 4 studies were classed as unclear due to a lack of description of outcome measures and 3 studies rated as high risk as data for some outcomes were not reported.

Publication bias

Funnel plots were produced for all outcomes, except flow-mediated dilatation (supplementary Figures 1-13). All funnel plots were asymmetrical, indicating publication bias.

Sensitivity analysis

Results from the sensitivity analysis are summarised in supplementary table 9. Heterogeneity was reduced in 16/33 outcomes. The most considerable reductions were in those outcomes with fewer studies such as short-term systolic and diastolic blood pressure and long-term total and high-density lipoprotein cholesterol and these results could alter the main findings. However, in the outcomes with more studies (e.g. total cholesterol, high-density lipoprotein cholesterol) it is unlikely that this sensitivity analysis will alter the main findings.

GRADE analysis

All outcomes were rated as very low or low quality evidence demonstrating that the estimate of effect for those outcomes is uncertain.

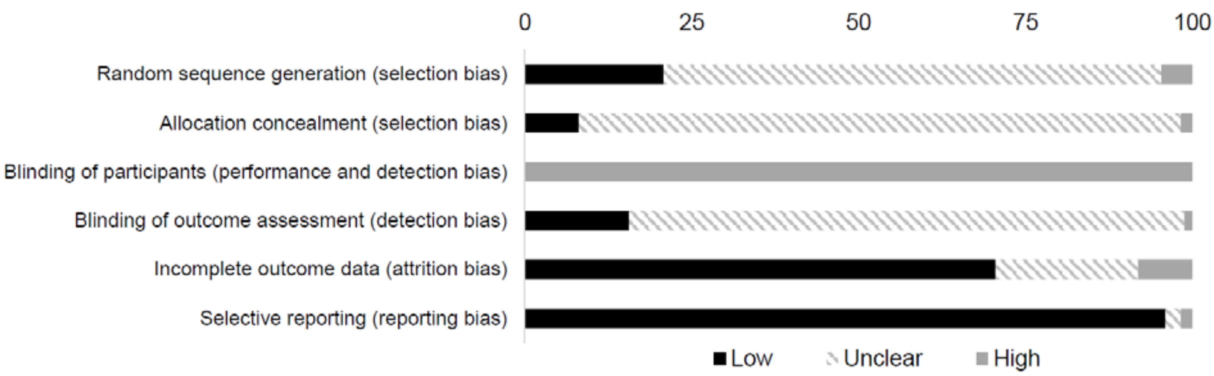

Figure 2. Risk of bias summary.

A summary of the change observed for each outcome at all durations is presented as mean difference and 95% CI in Figure 3.

Resting blood pressure and heart rate

Resting blood pressure and resting heart rate are presented in Table 3 and Supplementary Figures 14-17. Favourable reductions in systolic blood pressure (in the range 3-5 mmHg; $P \leq 0.04$) and diastolic blood pressure (in the range 1-5 mmHg; $P \leq 0.008$) were apparent after medium- and long-term term RET interventions (Table 1), with studies showing moderate to substantial heterogeneity (I^2 range of 64-86%). There were non-significant effects for mean arterial pressure and resting heart rate after short- and medium-term RET interventions (Table 3 and Supplementary Figures 16-17).

$\dot{V}O_2max$

The effect of RET on $\dot{V}O_2max$ is presented in Supplementary Figure 18. There was an improvement in $\dot{V}O_2max$ with RET and moderate heterogeneity (mean difference 2.07 [95% confidence interval 0.75, 3.39] ml/kg/min, $P = 0.002$; $\chi^2 = 11.35$, $I^2 = 30\%$, $P = 0.18$) in short-term studies (n=9; resistance arm: n = 177; control arm: n =131). In medium-term studies (n = 48; resistance arm: n = 767; control arm: n = 687) there was a significant improvement in $\dot{V}O_2max$ with RET and substantial heterogeneity (mean difference 1.07 [95% confidence interval 0.38, 1.76] ml/kg/min, $P = 0.002$; $\chi^2 = 160.15$, $I^2 = 71\%$, $P < 0.00001$). In long-term studies (n = 11; resistance arm: n = 213; control arm: n = 186) there was a significant improvement in $\dot{V}O_2max$ with RET (mean difference 1.22 [95% confidence interval 0.44, 2.0] ml/kg/min, $P = 0.002$; $\chi^2 = 10.22$, $I^2 = 2\%$, $P = 0.42$).

Table 3. The effects of short- (ST), medium- (MT) and long-term (LT) RET on resting blood pressure, mean arterial pressure and resting heart rate.

Outcome		Number of studies	Number of participants		Mean difference [95% CI]	*P* values	Heterogeneity
			RET	CON			
Systolic blood pressure (mmHg)	*ST*	4	59	57	-3.17 [-6.95, 0.6] †	0.1	$\chi^2 = 5.76$, $I^2 = 48\%$, $P = 0.12$
	MT	46	742	714	-4.02 [-5.92, -2.11] †	<0.0001*	$\chi^2 = 325.48$, $I^2 = 86\%$, $P < 0.00001$
	LT	8	188	178	-5.08 [-10.04, -0.13] †	0.04*	$\chi^2 = 19.46$, $I^2 = 64\%$, $P = 0.007$
Diastolic blood pressure (mmHg)	*ST*	4	59	57	-0.72 [-3.66, 2.22] †	0.63	$\chi^2 = 8.1$, $I^2 = 63\%$, $P = 0.04$
	MT	45	721	697	-1.73 [-2.88, -0.57] †	0.003*	$\chi^2 = 263.07$, $I^2 = 83\%$, $P < 0.00001$
	LT	7	177	169	-4.93 [-8.58, -1.28] †	0.008*	$\chi^2 = 22.07$, $I^2 = 73\%$, $P = 0.001$
Mean arterial pressure (mmHg)	*ST*	3	35	32	-3.31 [-6.86, 0.25] †	0.07	$\chi^2 = 6.61$, $I^2 = 70\%$, $P = 0.04$
	MT	10	136	132	-1.57 [-4.6, 1.46] †	0.31	$\chi^2 = 97.16$, $I^2 = 91\%$, $P < 0.00001$
Resting heart rate (bpm)	*ST*	2	16	14	-2.66 [-7.55, 2.23] †	0.7	$\chi^2 = 6.95$, $I^2 = 86\%$, $P = 0.008$
	MT	35	510	467	0.35 [-1.44, 2.13]	0.69	$\chi^2 = 266.11$, $I^2 = 87\%$, $P < 0.00001$
	LT	5	74	68	-0.48 [-3.12, 2.17] †	0.72	$\chi^2 = 6.83$, $I^2 = 41\%$, $P = 0.15$

*Indicates statistical significance. † Indicates favouring RET. RET – resistance exercise training, CON – control group, ST – short term, MT – medium term, LT – long term.

Flow-mediated dilatation

Eight studies reported flow-mediated dilatation, however due to missing data, only six studies (resistance arm: n = 68; control arm: n = 70), all medium-term, were included in the meta-analysis (Supplementary Figure 19). There was a significant improvement in flow-mediated dilatation favouring RET (1.69 [0.97, 2.41], $P < 0.0001$) with low heterogeneity ($\chi^2 = 0.72$, $I^2 = 0\%$, $P = 0.98$). One short-term study [25] and one long-term study [26] reported improvements in flow-mediated dilatation after RET.

Blood biomarkers

Blood biomarkers are presented in Table 4 and Supplementary Figures 20-27. Non-significant effects were observed for total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, triglycerides and C-reactive protein across the different study durations (Supplementary Figures 20-23 and 27). Significant reductions in fasted insulin ($P = 0.002$) and HOMA-IR ($P = 0.02$) were evident after medium-term but not long-term RET interventions. There was a significant reduction in fasted glucose after medium-term ($P = 0.02$) but not short- or long-term RET interventions.

Table 4. The effects of short- (ST), medium- (MT) and long-term (LT) RET on blood biomarkers

Blood marker		Number of studies	Number of participants		Mean difference [95% CI]	*P* values	Heterogeneity
			RET	CON			
Total cholesterol (mg/dL)	*ST*	3	80	66	-5.55 [-16.58, 5.48] †	0.32	χ² = 2.39, I² = 16%, P = 0.3
	MT	32	442	440	0.57 [-5.63, 6.77]	0.86	χ² = 190.82, I² = 84%, P < 0.00001
	LT	8	115	97	-8.71 [-30.83, 13.40] †	0.44	χ² = 71.91, I² = 90%, P < 0.00001
High-density lipoprotein cholesterol (mg/dL)	*ST*	3	80	66	0.82 [-5.40, 7.03]	0.56	χ² = 5.99, I² = 50%, P = 0.11
	MT	39	601	590	2.23 [-0.06, 4.51] †	0.06	χ² = 734.44, I² = 95%, P < 0.00001
	LT	9	179	160	2.79 [-0.69, 6.28] †	0.12	χ² = 12.33, I² = 35%, P = 0.14
Low-density lipoprotein cholesterol (mg/dL)	*ST*	3	80	66	-5.10 [-11.09, 0.90] †	0.1	χ² = 0.32, I² = 0%, P = 0.85
	MT	31	503	497	-2.86 [-8.77, 3.05] †	0.34	χ² = 292.46, I² = 90%, P < 0.00001
	LT	6	135	130	-3.69 [-10.99, 3.60] †	0.32	χ² = 2.39, I² = 0%, P = 0.79
Triglycerides (mg/dL)	*ST*	3	80	66	-3.63 [-17.45, 10.2] †	0.61	χ² = 0.14, I² = 0%, P = 0.93
	MT	37	590	575	-3.99 [-8.78, 0.8] †	0.29	χ² = 250.54, I² = 86%, P < 0.00001
	LT	6	135	130	-2.82 [-14.98, 9.33] †	0.65	χ² = 7.99, I² = 37%, P = 0.16
Fasted insulin (µU/ml)	*MT*	20	304	286	-0.59 [-0.97, -0.21] †	0.002*	χ² = 84.86, I² = 78%, P < 0.00001
	LT	4	89	90	-0.60 [-1.93, 0.72] †	0.37	χ² = 45.43, I² = 93%, P < 0.00001
HOMA-IR	*MT*	9	96	88	-1.22 [-2.29, -0.15] †	0.02*	χ² = 94.62, I² = 92%, P < 0.00001
	LT	3	38	33	-0.18 [-0.64, 0.27] †	0.6	χ² = 1.45, I² = 0%, P = 0.48
Fasted glucose (mg/dL)	*ST*	2	64	58	-3.39 [-6.90, 0.11] †	0.06	χ² = 1.66, I² = 40%, P = 0.2
	MT	33	499	485	-2.39 [-4.47, -0.31] †	0.02*	χ² = 318.33, I² = 90%, P < 0.00001
	LT	7	135	136	-0.07 [-2.80, 2.67] †	0.96	χ² = 46.09, I² = 87%, P < 0.00001
C-reactive protein (mg/L)	ST	2	41	41	-0.43 [-1.05, 0.19] †	0.07	χ² =1.58, I² = 37%, P = 0.21
	MT	12	199	195	-0.28 [-0.72, 0.15] †	0.20	χ² = 44.57, I² = 75%, P < 0.00001

* Indicates statistical significance. † Indicates favouring RET. RET – resistance exercise training, CON – control group, ST – short term, MT – medium term, LT – long term, HOMA-IR – insulin resistance.

Sub-group analyses

When comparing healthy young adults ≤40 years (n = 44) with healthy older adults ≥41 years (n = 50), there was a greater magnitude of cardio-metabolic benefit from RET in the older populations (supplementary tables 5 and 6). There were significant reductions in systolic blood pressure with medium-term RET interventions for healthy older adults compared to healthy younger adults (-4.36 [-5.73, -2.99] mmHg, P < 0.00001, versus -0.56 [-1.57, 0.44] mmHg, P = 0.27, respectively) (supplementary table 5 and 6). In the healthy older adults there were significant improvements in systolic blood pressure, diastolic blood pressure, mean arterial pressure, resting heart rate, total cholesterol, high-density lipoprotein cholesterol, triglycerides, fasted insulin, fasted glucose and C-reactive protein following medium-term interventions compared to younger adults for the same intervention duration. Significant improvements after long-term interventions were also apparent for diastolic blood pressure, $\dot{V}O_2max$, total cholesterol and fasted glucose in healthy older adults ≥41 years compared to younger adults.

There were greatest improvements in medium-term LDL cholesterol, short- and medium-term $\dot{V}O_2max$, and short-term systolic and diastolic blood pressure among older adults (≥41 years) with elevated cardio-metabolic risk or cardio-metabolic disease (n = 42) after medium-term interventions, compared to healthy older adults. For example, the largest reduction in systolic blood pressure following medium-term RET interventions was observed in older adults ≥41 years with elevated cardio-metabolic risk or disease (-8.80 [-9.90, -7.69] mmHg, P < 0.00001) compared to the healthy older adults (-4.36 [-5.73, -2.99] mmHg, P < 0.00001).

Adverse events

One hundred and twenty-three RCTs (71%) did not report the occurrence of adverse events. Fifty studies (29%) reported information on adverse events and 17 of these reported that no adverse events occurred. Of the 50 studies reporting adverse events, 16 studies reported more than one adverse event occurring. Musculoskeletal injuries (e.g. lower back pain, knee pain) as a result of the intervention were reported in 20 studies (n = 20/50; 40%), with more than one adverse event being reported in 15 of the 20 studies. Two studies (4%) detailed discomfort and muscle soreness related to RET. Illness or injury unrelated to RET were reported in seven (14%) studies. Three studies (6%) reported that participants suffered injuries but the details and whether they were related to the intervention, was unclear. Syncope, possibly related to the intervention, was reported in three studies (6%). Cardiac issues (e.g. myocardial infarction, angina) thought to be unrelated to the RET were reported in four (8%) studies. Respiratory problems, unrelated to the intervention, were reported in two (4%) and hypoglycaemia in a further two (4%) studies. Four studies (8%) identified participants who underwent elective surgery unrelated to the study. Five studies (10%) reported a newly diagnosed condition or change in medication. Other adverse events reported only once included death (car crash), cerebral stroke, abdominal hernia and deep vein thrombosis; these were not associated with RET. Personal or professional issues resulting in withdrawal from the programme were reported in 5 (10%) studies.

DISCUSSION

Resistance exercise training had a positive impact on cardio-metabolic health, via improvements in resting blood pressure, $\dot{V}O_2max$ and blood biomarkers of cardio-metabolic risk. These improvements were most convincing for medium-term (7-23 weeks) interventions, which is likely to reflect the higher volume of published studies compared to short- (< 6 weeks) and long-term (≥ 24 weeks) intervention durations. Relatively few studies have primarily investigated the cardio-metabolic health benefits of RET in clinical populations, particularly those at elevated risk of cardiovascular events. There is limited evidence of adverse events associated with RET with only 12% of studies included in the review reporting musculoskeletal injuries. Other studies reported transient levels of muscle soreness following RET, which is common after unaccustomed muscular exercise [27-29]. Therefore, we suggest that RET is a safe exercise option for both healthy and clinical populations.

There was a positive effect of RET on systolic and diastolic blood pressure. The reductions observed are of similar magnitude to those after aerobic exercise interventions [30-33], and could suggest a dose-response relationship for interventions of varying durations. Furthermore, given that hypertension is a global cause of mortality [34], the pronounced effects of RET on blood pressure outcomes in

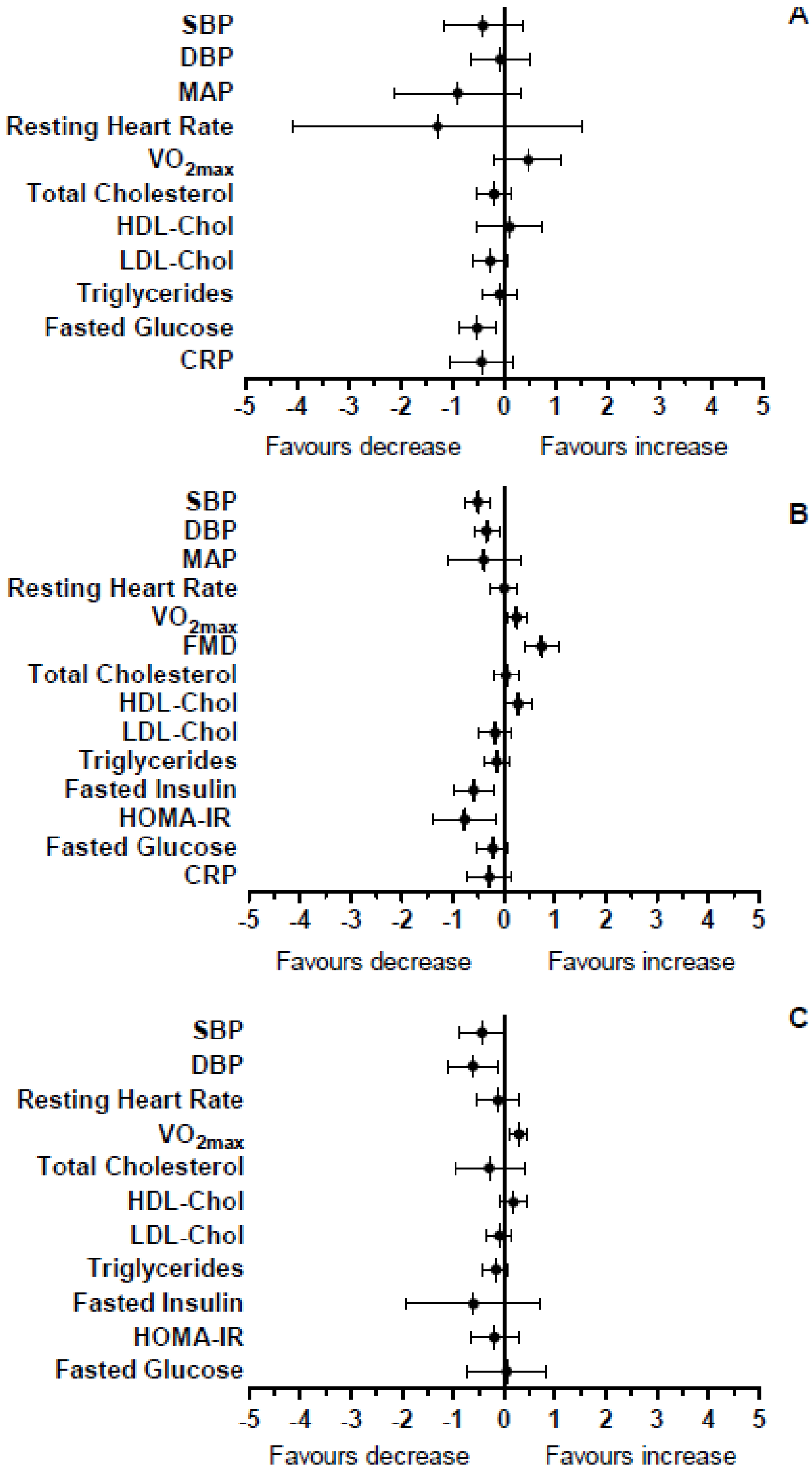

Figure 3. (A) Short-term, (B) medium-term, (C) long-term effects of resistance exercise training as standardised mean difference and 95% CI. SBP - systolic blood pressure, DBP - diastolic blood pressure, MAP - mean arterial pressure, VO2max - maxium oxygen consumption, FMD - flow mediated dilatation, HDL-Chol - high density lipoprotein cholesterol, LDL-Chol - low density lipoprotein cholesterol, HOMA-IR - insulin resistance, CRP - c-reactive protein.

older populations observed in our subgroup analyses suggest that RET could be an effective non-pharmacological strategy for the prevention and/or control of hypertension in older adults who are at elevated cardio-metabolic risk.

The effect of RET on mean arterial pressure and resting heart rate was not statistically significant. Although resting heart rate may be less sensitive to change after RET, the lack of effect on mean arterial pressure (particularly for medium-term studies) could be due to few studies reporting mean arterial pressure in comparison to systolic or diastolic blood pressure. Additionally, diastolic blood pressure has a greater influence on mean arterial pressure than systolic blood pressure and, due to the less pronounced effect of RET on diastolic blood pressure, this could have impacted upon the significance of mean arterial pressure.

Low cardiopulmonary fitness has an indirect effect on cardiovascular disease risk and is partially (40-60%) mediated by cardiovascular risk factors including hypertension, hypercholesterolemia, obesity and fasting glucose [35]. Therefore, the beneficial effects of RET on $\dot{V}O_2max$ is important. Traditionally, RET has not been used to provide a stimulus for improving cardiopulmonary exercise capacity, however our findings suggest that RET may be a reasonable choice for improving this health outcome. Improvements in $\dot{V}O_2max$ after RET were modest (short-term: 2.38 [0.76, 4.00] ml/kg/min; medium-term: 1.13 [0.50, 1.76] ml/kg/min; long-term: 1.23 [0.6, 1.87] ml/kg/min). However, larger effects were observed for older adults at elevated cardio-metabolic risk. This is clinically important since it suggests that RET may contribute to reducing the risk of cardiovascular morbidity and mortality in high risk populations [36]. On the other hand, it is also possible that those who participated in RET also increased their participation in aerobic activity. Exercise training outside of RET interventions was generally not monitored and may account for some of the change in $\dot{V}O_2max$ after RET.

Endothelial dysfunction is associated with cardiovascular disease and the ageing process. Endothelial dysfunction is linked to a decrease in nitric oxide availability, which can be improved through exercise [37]. A deterioration in flow-mediated dilatation of approximately 1% is associated with a 13% increased risk of future cardiovascular events [38, 39]. We found improvements in endothelial function (flow-mediated dilatation) with RET programmes that lasted 7-23 weeks. This is likely to result from shear stress-induced adaptations in nitric oxide metabolism resulting from muscular contractions, resting heart rate and blood pressure changes during RET [26]. Shear-stress induced adaptations may not be restricted to blood vessels within the active skeletal muscles, as exercise programmes that are performed predominantly with the legs induce improvements in brachial artery flow-mediated dilatation [40]. Therefore, RET may be an effective stimulus for improving flow-mediated dilatation, potentially reducing the risk of cardio-metabolic disease.

The most favourable changes in blood biomarkers were apparent in short- and medium-term studies in the pooled analysis. The lower number of longer-term studies may have reduced the level of statistical power required to detect significant changes. We found greater reductions in low-density lipoprotein cholesterol, triglycerides and fasted glucose among older adults. There were also significant reductions in C-reactive protein after short- and medium-term RET among older adults at elevated cardio-metabolic risk (Table 4 and Supplementary Table 7). Reductions in C-reactive protein, fasted glucose and insulin, and HOMA-IR could have been mediated by the effect of RET on body composition, including an increase in skeletal muscle mass and reduction in fat mass, and the resulting impact on adipokine secretion [15, 41], insulin sensitivity [42] and glucose transport [43, 44]. These improvements in metabolic functioning following RET could have important clinical implications for the prevention and treatment of metabolic syndrome, type 2 diabetes mellitus and cardiovascular disease [41, 32, 45, 46].

Future studies on RET interventions should monitor or control for the potential confounding influence of aerobic exercise outside of the intervention. It is unclear whether improvements in $\dot{V}O_2max$ after RET are more attributable to the cardiopulmonary stimulus of RET leading to improved oxygen transport (via increased cardiac stroke volume) or metabolic adaptations resulting in improved utilisation of oxygen at the level of skeletal muscle. Improvements in $\dot{V}O_2max$ following medium- to long-term programmes of aerobic exercise training tend to be greater and mainly reflect an increase in cardiac stroke volume in previously untrained individuals [47, 48]. The relative importance of, and potential to maximise central, systemic and peripheral adaptations, by altering the characteristics of RET (e.g. sets, repetitions, rest etc.) warrants further research. Furthermore, additional high-quality research is also required to formulate the optimal design of a RET programme to promote cardiovascular health and risk factor management in middle-aged and clinical populations.

Limitations

The main findings of this systematic review need to be considered in the context of some key limitations, including restricting the search to two electronic databases, language bias and unexplained statistical heterogeneity for some of the analyses. Publication bias was also evident, and is probably attributable to inadequate data analysis, poor methodological quality and/or varying sample sizes of included studies. It is unlikely that selective outcome reporting influenced the funnel plots as 90.6% of the studies were rated as low risk for this outcome. Additionally, poor methodological quality of some of the included studies could have affected the estimates of the outcomes. Although all the included studies were RCTs, few studies adequately reported the randomisation process (n = 36), allocation concealment (n = 14), or blinding of outcome assessment (n = 27). Therefore, many studies were rated as unclear bias in multiple categories and this may have contributed to the lack of reduction in heterogeneity in the sensitivity analyses. Additionally, some data were not pooled due to lack of access to the mean (SD) scores.

Reporting must improve, as many studies had incomplete descriptions of RET programmes and progression, small sample sizes, inadequate documentation of adherence and lacked detail regarding the timing of blood sampling in relation to the last bout of exercise (potentially influencing circulating levels of blood biomarkers). Improved reporting of trials may also improve the quality of evidence, as all outcomes in this review were graded as either very low or low quality, and higher-quality reporting of outcomes may alter the effect estimates. Authors should follow guidelines when reporting trials such as the TIDieR checklist and guide [49].

Studies of varying duration are needed, as the majority included in our systematic review involved medium-term interventions. In addition, data analyses were often based only on participants who successfully completed the training intervention, rather than applying an intention to treat analysis. This could have altered the study results [23, 50]. Finally, cardiorespiratory fitness levels of participants prior to a RET intervention is likely to influence training-induced adaptations and this should be considered in future research.

CONCLUSION

RET was a safe and effective exercise modality for inducing improvements in resting blood pressure, flow-mediated dilatation, blood biomarkers of cardio-metabolic risk and cardiopulmonary fitness in adults. The effects were more pronounced in older adults (≥41 years) and those with elevated cardio-metabolic risk or disease.

CONFLICT OF INTEREST AND CONTRIBUTION

All authors declare that they have no conflict of interest. All authors made a substantial contribution to this paper.

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SUMMARY

WHAT ARE THE NEW FINDINGS?

- The results suggest that RET improves several cardiometabolic risk factors; however, the quality of the evidence was low and there were no data on hard clinical end-points.
- Improvements in cardiometabolic risk factors were more pronounced in individuals with elevated cardiometabolic risk or disease when compared with younger healthy adults.
- Few adverse events were reported, suggesting that RET is safe.

SUPPLEMENTARY DOCUMENTS

Table 1. Search Strategy

Database	Search Strategy
MEDLINE	1. ((strength$ or resist$ or weight$) adj3 training).tw. 2. (progressive resist$).tw. 3. or/1-2 4. Exercise/ 5. Exercise Therapy/ 6. exercise$.tw. 7. or/4-6 8. (Resist$ training or strength$).tw. 9. and/7-8 10. or/3,9 11. randomized controlled trial.pt 12. controlled clinical trial.pt. 13. Randomized Controlled Trials/ 14. Random Allocation/ 15. Double Blind Method/ 16. Single Blind Method/ 17. or/11-16 18. Animals/ not Humans/ 19. 17 not 18 20. and/10,19
The Cochrane Library (Wiley)	#1 ((strength* or resist* or weight*) NEAR/3 training):ti,ab,kw #2 (progressive resist*):ti,ab,kw #3 #1 OR #2 #4 MeSH descriptor Exercise, this term only #5 MeSH descriptor Exercise Therapy, this term only #6 (exercise*):ti,ab,kw #7 (#4 OR #5 OR #6) #8 (resist* or strength*):ti,ab,kw #9 (#7 AND #8) # 10 (#3 OR #9)

Table 2. Study characteristics

Author & year	Country	Population	Duration & frequency	Intervention	Timing of outcomes	Funding & conflicts of interest
Ades et al. 1996	USA	RT = 69.9 ± 4 yrs CON = 70.7 ± 5 yrs Male and female Healthy elderly	12 weeks 3 d per week	Supervision not reported Free weights and weight machines 3 sets of 8 reps at 50% 1RM with progression to 80% by week 9	Baseline and 12 weeks	Grants from National Institute of Health and General Clinical Research Centres.
Afshar et al. 2010	Iran	RT = 51 ± 16.4 yrs AT = 50.7 ± 21.1 yrs CON = 53 ± 19.4 yrs Males Haemodialysis	8 weeks	Supervised by a physician Ankle weights 2 sets of 8 reps progressed to 3 sets	Baseline and 8 weeks	
Ahmadizad et al. 2007	Iran	RT = 40.9 ± 3.2 yrs AT = 41.3 ± 5.1 yrs CON = 38.6 ± 3.2 yrs Male Sedentary obese	12 weeks 3 d per week	Supervision not reported Circuit resistance training 4 sets of 12 maximal reps at 11 stations 50–60% of 1RM in each station	Baseline and 12 weeks	Tarbiat Moallem University of Sabzevar in Iran.
Ahmadizad et al. 2014	Iran	Total cohort 23.4 ± 0.6 yrs Male Sedentary overweight	8 weeks 3 d per week	Supervised Free weights, weight machines and body weight 1-2 weeks: 1 set of 10 reps 3-8 weeks: 2–3 sets of 20–30 reps NP: constant moderate intensity DUP: rotated loading LP: volume was decreased and the training intensity was increased each week	Baseline and 8 weeks	
Almenning et al. 2015	Norway	Total cohort 27.2 ± 5.5 yrs Females Polycystic ovary syndrome	10 weeks 3 d per week	Supervised by an exercise physiologist at least 1 session a week 3 sets of 10 reps at 75% 1RM	Baseline and 10 weeks	The Norwegian Fund for Research in Sports Medicine.
Anderson et al. 2004	USA	RT = 26.4 ± 7.5 yrs AT = 20.9 ± 2.4 yrs CON = 26.6 ± 6.5 yrs Males Healthy sedentary	6 weeks 3 d per week	Supervision not reported Free-weight and machine exercises 2 sets of 10-15 reps	Baseline and 6 weeks	
Andersen et al. 2008	Denmark	RT = 44 ± 9 yrs Fitness Training = 45 ± 9 yrs CON = 42 ± 8 yrs Females Trapezius myalgia	10 weeks 3 d per week	Supervised Free-weight and machine exercises 3 sets Intensity progressively increased from 12RM to 8RM	Baseline and 10 weeks	Grants from Danish Medical Research Council and the Danish Rheumatism Association.
Andersen et al. 2014	Denmark	Total cohort = 68.2 ± 3.2 yrs Males Healthy elderly	16 weeks 2 d per week	Supervised Free-weight and machine exercises 0-4 weeks: 3 sets of 16-20 reps 5-8 weeks: 3 sets of 12 reps	Baseline and 16 weeks	Supported by the FIFA Medical Assessment and Research Centre, The Danish Ministry of

				9-12 weeks: 3 sets of 10 reps 13–16 weeks: 4 sets of 8 reps		Culture, and Nordea-fonden, Denmark.
Andersen et al. 2016	USA	Total cohort = 68.1 ± 2.1 yrs Healthy elderly	36 weeks 2 d per week	Supervised Free weight, weight machines and body weight 0-4 weeks: 3 sets of 16–20RM 5-8 weeks: 3 sets of 12RM 9-12 week: 3 sets of 10RM 13-52 weeks: 4 sets of 8RM	Baseline and 36 weeks	Supported by the FIFA-Medical Assessment and Research Centre (Project 31964). The Danish Ministry of Culture (Kulturministeriets Udvalg for Idrætsforskning) (TKIF 2010-027), and Nordea-fonden (02-2011-4360).
Arora et al. 2009	India	RT = 49.6 ± 5.2 yrs AT= 52.2 ± 9.3 yrs CON = 58.4 ± 1.8 yrs Male and female Type 2 diabetes	8 weeks 2 d per week	Supervised 3 sets of 10 reps at 60-100% 1RM	Baseline and 8 weeks	Grant from University Grants Commission, Delhi, India.
Asad et al. 2012	Iran	RT = 21 ± 1.6 yrs AT = 22 ± 0.9 yrs Concurrent = 21.4 ± 2.1 yrs CON = 21.4 ± 1.1 yrs Male Healthy sedentary	8 weeks 3 d per week	Supervision not reported Free weights and weight machines 3 sets of 10-15 reps Weeks 2-8: first set for 10-12 reps, 8-10 reps for second set and 4-8 reps for third set	Baseline and 8 weeks	
Augusto Libardi et al. 2012	Brazil	RT males = 47 ± 4.5 yrs RT females = 53.7 ± 3.7 yrs CON males = 49.5 ± 5.6 yrs CON females = 51.2 ± 6.4 yrs Males and females Healthy sedentary	16 weeks 3 d per week	Supervision not reported Free-weight, machine exercises and body weight 3 sets of 10 reps 9-16 weeks: 8 reps	Baseline and 16 weeks	Supported by Conselho Nacional de Desenvolvimento Científico e Tecnológico
Azarbayjani et al. 2014	Iran	RT = 23.1 ± 1.4 yrs AT = 23.3 ± 1.3 yrs Concurrent = 22.9 ± 1.7 yrs CON = 22.9 ± 1.7 yrs Males Healthy sedentary	12 weeks 3 d per week	Supervision not reported Free-weight and machine exercises 3 sets of 10 reps at 70% 1RM	Baseline and 12 weeks	Grant (90084702) from the Islamic Azad University, Central Tehran Branch grants commission.
Badrov et al. 2013	Canada	IHG3 = 23 ±4 yrs IHG5 = 27 ±6 yrs CON = 24 ± 8 yrs Females Healthy sedentary	8 weeks IHG3 - every other day IHG5 - five consecutive days	Supervision for 2 sessions a week Isometric hand grip at 30% MVC	Baseline, 4 and 8 weeks	Supported by the University of Windsor (810043; 809264; 808316; CLM), the Canadian Institutes of Health Research, Heart and Stroke/Richard Lewar Centre of Excellence Postdoctoral Fellowship, and an Ontario Graduate Scholarship.
Baldi & Snowling 2013	New Zealand	RT= 46.5 ± 2.1 yrs CON = 50.1 ± 1.3 yrs Females	10 weeks 3 d per week	Supervised 1-2 circuits of 12 reps at 10RM (upper body) or 15RM (lower body)	Baseline and 10 weeks	

		Type 2 diabetes				
DeBarros et al. 2010	Brazil	RT = 31.8 ± 4.9 yrs CON = 32.4 ± 5.4 yrs Female Type 2 diabetes	24-34 weeks 3 d per week	Supervised by the researcher for 1 session a week Elastic resistance band circuit Exercise intensity was controlled using a perceived exertion scale. Subjects advised to maintain an exercise intensity close to 5 or 6, which corresponds to a “somewhat heavy”.	Baseline and 24 weeks	Supported by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior with master’s fellowship grant.
Beck et al. 2013 Beck et al. 2013	USA	RT = 21.1 ± 2.5 yrs AT = 20.1 ± 1.1 yrs CON = 21.6 ± 2.9 yrs Normotensive CON = 21.6 ± 2.7 yrs Male and female young Pre-hypertensives RT = 21.1 ± 0.6 yrs AT = 20.1 ± 0.9 yrs CON = 21.6 ± 0.8 yrs Normotensive CON = 21.6 ± 0.7 yrs Male and female Pre-hypertensives	8 weeks 3 d per week	Supervision not reported Weight machines 2 sets of 8–12 reps to volitional fatigue Weight machines 2 sets of 8–12 reps to volitional fatigue	Baseline and 8 weeks	Supported, in part, by a National Institutes of Health pre-doctoral training grant (NIH 5-T32-HL083810-04) awarded by the University of Florida Hypertension Centre. Supported, in part, by a National Institutes of Health predoctoral training grant (NIH 5-T32-HL083810-04) awarded to D.T.B. by the University of Florida Hypertension Centre.
Bell et al. 2000	Canada	Total cohort = 22.3 ± 3.3 yrs Male and female Physically active	12 weeks 3 d per week	Supervision not reported Free-weight and machine exercises 2-6 sets of 4-12 reps	Baseline, 6 and 12 weeks	
Beltran Valls et al. 2014	Italy	RT = 72 ± 1 yrs CON = 72 ± 1 yrs Male and female Healthy elderly	12 weeks 2 d per week	Supervised Weight machines 1-2 weeks: 4 sets of 15 reps at 40–50 % 1RM 3-12 weeks: 3–4 sets of 10–12 reps at 70 % of baseline 1RM	Baseline and 12 weeks	Grants from the University of Rome “Foro Italico” (Research 2009) to D. C. The Lazio Regional Municipality (Agreement CRUL-Lazio n. 12650/2010) supported the post-doc scholarship to ID.
Bertuzzi et al. 2013	Brazil	RT = 31 ± 5 yrs RT with WBV = 34 ± 6 yrs CON = 33 ± 7 yrs Sex not reported. Long-distance runners	6 weeks 2 d per week	Supervised Weight machines 1–2 weeks: 3 sets at 8-10RM 3–4 weeks: 4 sets at 6-8RM 5–6 weeks: 6 sets at 4–6RM	Baseline and 6 weeks	Post-doctoral grant São Paulo Research Foundation (FAPESP: 08-50934-1) and master scholarships from São Paulo Research Foundation (FAPESP: 2010/13913-6 and 2011/02769-4, respectively).
Bishop & Jenkins 1996	Australia	Only report cohort was 17-24 yrs Males	6 weeks 3–4 d per week	Supervised Weight machines 3-6 sets of 1-3 or 12-15 reps	Baseline and 6 weeks	

		Physically active				
Bishop et al. 1999	Australia	Only report cohort was 18-42 yrs Female Cyclists	12 weeks 2 d per week	Supervised Weight machines 5 sets to failure at 2-8RM	Baseline, 6 and 12 weeks	
Boardley et al. 2007	USA	RT = 74.1 ± 6.2 yrs Combined = 75.3 ± 6 yrs AT = 73.2 ± 6.6 yrs CON = 75.9 ± 7.7 yrs Male and female Healthy elderly	16 weeks 3 d per week	Supervised by project staff for 2 sessions a week Elastic resistance bands 1-2 weeks: 1 set of 10 reps 3-16 weeks: 2 sets of 12 reps Theraband colour was changed so that it provided sufficient resistance to produce mild fatigue at the final rep	Baseline, 8 and 16 weeks	Funded by the National Institute for Nursing Research grant #R01 NR04929. The Hygenic Corporation supplied the Thera-Band but had no other role in the study.
Borges & Carvalho 2014	Brazil	RT = 64.1 ± 12.5 yrs CON = 67.8 ± 9 yrs Male and female COPD	Completed a minimum of 3 sessions	Supervised Free weights and weight machines 2 sets of 9 reps Initial load was 80% 1RM and adjusted in subsequent sessions based on symptoms, Borg Dyspnea Scale scores, and patient fatigue	Evaluated on the second day in hospital, at discharge, and 30 days post discharge	
Brentano et al. 2008	Brazil	Age not reported Female Post-menopausal	24 weeks 3 d per week	Supervision not reported Free-weight and machine exercises RT circuit: 2-3 sets of 10-20 reps at 45-60% 1RM RT: 2-4 sets of 6-20 reps at 45-80% 1RM	Baseline, 8, 16 and 24 weeks	
Brito et al. 2013	Brazil	Age not reported. Male and female HIV/AIDS	24 weeks. 3 d per week	Supervised Free-weight and machine exercises 3 sets of 8-10 reps at 80% 1RM	Baseline and 24 weeks	
Broeder et al.1992	USA	Only report cohort 18-35 years Males Physically active	12 weeks 4 d per week	Supervised Free-weight and machine exercises 1-2 weeks: 10-12 reps 3-12 weeks: 10-12 reps on the first set, 8-10 reps on the second set, and 6-8 reps on the third set	Baseline and 12 weeks	
Brooks et al. 2007	USA	RT = 66 ± 2 yrs CON = 66 ± 1 yrs Males and females Type 2 diabetes	16 weeks 3 d per week	Supervision not reported Weight machines 3 sets of 8 reps 1-9 weeks: 60% 1RM 10-14 weeks: 70-80% 1RM	Baseline and 16 weeks	Funded, in part, by the Brookdale Foundation, the USDA ARS agreement 58-1950-9-001, the NIH General Clinical Research Center M01 RR000054, and the International Life Sciences Institute North America.

Buchner et al. 1997	USA	RT = 74 yrs AT = 75 yrs AT + RT = 75 yrs CON = 75 yrs Male and female Healthy elderly	24-26 weeks 3 d per week	Supervised Weight machines 2 sets of 10 reps with the first set at 50-60% 1RM and the second set 75% 1RM	Baseline and 24 weeks Follow up at 28 weeks	Grants from the National Institute on Aging (UO1 AG09095), Centres for Disease Control and Prevention (R48 CCR002181), and the Department of Veterans Affairs.
Camargo et al. 2008	Brazil	RT = 29 ± 3 yrs AT = 29 ± 4 yrs CON = 30 ± 4 yrs Males Healthy sedentary	12 weeks 3 d per week	Supervised Weight machines 3 sets of 15 reps at 60% of 1RM	Baseline and 12 weeks	Partially supported by a grant from FIPE-Hospital de Clinicas de Porto Alegre and FAPICC.
Castaneda et al. 2002	USA	RT = 66 ± 2 yrs CON = 66 ± 1 yrs Male and female Type 2 diabetes	16 weeks 3 d per week	Supervision not reported 3 sets of 8 reps Weight machines 1-8 weeks: 60-80% of baseline 1RM 10-14 weeks: 70-80% of mid-study 1RM	Baseline and 16 weeks	Funded, in part, by Brookdale foundation in U.S. Department of Agriculture, the National Institutes of Health Clinical Research Centre and the International Life Sciences Institute, North America.
Christensen et al. 2014	Denmark	RT = 34.4 ± 7.6 yrs CON= 35.8 ± 8.9 yrs Male Disseminated germ cell cancer	9 weeks 3 d per week	Supervised 1-2 weeks: 3 sets of 15 reps at 15RM 3-9 weeks: 4 sets of 10 reps at 10-12RM	Baseline and 9 weeks	Supported by Copenhagen University Hospital, the Beckett Foundation and the Centre for Integrated Rehabilitation of Cancer Patients.
Colado et al. 2009	Spain	RT = 54 ± 2.8 yrs Aquatic = 54.7 ± 2 yrs CON = 52.9 ± 1.9 yrs Female Post-menopausal	24 weeks	Supervised Free-weight, machine and body weight exercises 1-12 weeks: 8 exercise circuit, 1 set of 20 reps with 30 sec active rest between sets, 1 set upper body, 2 sets lower body. 12-24 weeks: 10 exercise circuit, 1 set of 20 reps	Baseline and 24 weeks	Funding (PMAFI-PI-01/1C/04) from the Research Funds Program of the Catholic University San Antonio in Murcia (Spain).
Conceição et al. 2013	Brazil	RT = 53.4 ± 4 yrs CON = 53 ± 5.7 yrs Females Post-menopausal	16 weeks 3 d per week	Supervision not reported Free-weight, machine and body weight exercises 1-8 weeks: 3 sets of 10 reps at 10RM with 60 s rest between sets 9-16 weeks: 3 sets of 8 reps at 8RM with 90 s rest between sets	Baseline and 16 weeks	Funding from the São Paulo Research Foundation (FAPESP) for financial support (2012/09709-0).
Courneya et al. 2007 Courneya et al. 2010	Canada	RT= 49.5 yrs AT = 49 yrs Control = 49 yrs Females Breast cancer	18 weeks Not reported	Supervised Weight machines 2 sets of 8-12 reps at 60% to 70% 1RM	Baseline, 9 (only for subjective measures) and 18 weeks	None reported Grant from the Canadian Breast Cancer Research Alliance. Also supported by a Doctoral Research Award from the Canadian Institutes of Health

						Research, the Canada Research Chairs Program, a Research Team Grant from the National Cancer Institute of Canada with funds from the Canadian Cancer Society and the National Cancer Institute of Canada Canadian Cancer Society Socio-behavioural Cancer Research Network and a New Investigator Award from the Heart and Stroke Foundation of Canada.
Croymans et al. 2013	USA	RT = 21.5 yrs Control = 22 yrs Male Sedentary obese	12 weeks 3 d per week	Supervised Free-weight, machine and body weight exercises 1-2 weeks: 2 sets of 12–15 reps at 100% of estimated 12–15RM 3–7 weeks: 3 sets of 8–12 reps, at 100% of 8–12RM 8–12: weeks: 6–8 reps at 6–8RM	Baseline and 12 weeks	Supported by the American Heart Association (BGIA no 0765139Y to CKR), the National Heart, Lung and Blood Institute (P50 HL105188 to CKR) and the National Centre for Advancing Translational Sciences through UCLA CTSI Grant UL1TR000124 RAH and the American Heart Association (10SDG305006).
Davidson et al. 2009	USA	FEMALES: RT = 67.6 ± 4.2 yrs AT = 69.1 ± 6.5 yrs Combined = 66.5 ± 5.3 yrs CON = 66.7 ± 3.7 yrs MALES: RT = 67.4 ± 6 yrs AT = 68.8 ± 6 yrs Combined = 67.1 ± 5 yrs CON = 67.4 ± 3.8 yrs Male and female Sedentary obese	24 weeks 3 d per week	Supervision not reported Free-weight, machine and body weight exercises 1 set Each exercise was performed until volitional fatigue	Baseline and 24 weeks	Supported by research grant MT 13448 from the Canadian Institutes of Health Research.
DeLima et al. 2012	Brazil	RT linear periodization = 25.2 ± 4.4 yrs RT undulating periodization = 27.4 ± 2.8 yrs CON = 23.4 ± 1.3 yrs Female Healthy sedentary	12 weeks 3 d per week	Supervised Free-weight, machine and body weight exercises 3 sets until failure RT linear: 3 sets of 30RM, in the second week 3 sets of 25RM, in the third week 3 sets of 20RM and in the fourth week 3 sets of 15RM RT undulating: weeks 1, 3, 5, 7, 9 and 11, participants trained on days 1 and 2 with 3	Baseline and 12 weeks	

				sets of 30RM and on days 3 and 4 with 3 sets of 25RM. Weeks 2, 4, 6, 8, 10 and 12, participants trained on days 1 and 2 with 3 sets of 20RM and on days 3 and 4 with 3 sets of 15RM.		
DeSouza et al. 2014	Brazil	RT = 25.9 ± 6.4 yrs Interval = 24 ± 7.5 yrs Concurrent = 22.5 ± 3.9 yrs CON = 22.1 ± 2.4 yrs Male Physically active	8 weeks 2 d per week	Supervision not reported 3-5 sets of 6-12RM	Baseline and 8 weeks	
Deibert et al. 2011	Germany	RT = 55.5 ± 4.8 yrs RT + supplement = 55.9 ± 3.5 yrs CON = 55.8 ± 5.5 yrs Male Healthy sedentary	12 weeks 2 d per week	Supervised Weight machines 1–4 weeks: 25 reps 5–9 weeks: 15 reps 10-12 weeks: 10 reps	Baseline and 12 weeks	Grants from Almased Wellness Corp.
DeVallance et al. 2016	USA	RT = 51 ± 3 yrs CON = 44 ± 3 yrs Male and female Metabolic syndrome	8 weeks 3 d per week	Supervision not reported Weight machines 3 sets of 8-12 reps 1–2 weeks: 60% of 1RM 3–4 weeks: 70% of 1RM 5–6 weeks: 80% of 1RM 7–8 weeks: 85% of 1RM	Baseline and 8 weeks	Supported in part by the American Heart Association Grant 11CRP7370056, National Heart, Lung, and Blood Institute Grant T32-HL-090610, and National Institute of General Medical Sciences of the National Institutes of Health under Award U54-GM-104942 and 1P20 GM109098, STEM Mountains of Excellence Fellowship.
Donges et al. 2010	Australia	Age not reported. Male and female Healthy sedentary	10 weeks 3 d per week	Supervised Weight machine exercises 10RM that is reported to approximate with 75% of a 1RM	Baseline and 10 weeks	Funded by Charles Sturt University.
Dunstan et al. 1998	Australia	RT Circuit = 50.3 ± 7.7 yrs CON = 51.1 ± 7.6 yrs Male and female Type 2 diabetes	8 weeks 3 d per week	Supervised Free-weight, machine and body weight exercises 1-2 weeks: 2 sets of 10-15 reps at 50–55% 1RM 3-8 weeks: 3 sets of 10-15 reps at 50–55% 1RM	Baseline and 8 weeks	Supported by a National Health and Medical Research Council program grant ‘Studies in hypertension and vascular disease’.
Edge et al. 2006	Australia	Total cohort = 18 ± 1 yrs Female Physically active	5 weeks	Supervision not reported Free weights and machines 1-2 weeks: 2-3 sets of 15-20 reps 3-5 weeks: 3-5 sets of 15-20 reps Set 1 at 70% 3RM; set 2 at 60% 3RM; sets 3–5 at 50% 3RM	Baseline and 5 weeks	

Egana et al. 2010	Ireland	RT = 69 ± 5 yrs CON = 64 ± 4 yrs Female Healthy elderly	12 weeks 2 d per week	Supervised Therabands 2 sets at 100% 10RM	Baseline and 12 weeks	
Elliott et al. 2002	UK	RT = 58 ± 4 yrs CON = 53 ± 3 yrs Female Post-menopausal	8 weeks 3 d per week	Supervision not reported 3 sets of 8 reps at 80% 10RM	Baseline and 8 weeks Follow-up at 16 weeks	
Fahlman et al. 2002	USA	RT = 73 ± 3 yrs AT = 76 ± 5 yrs CON = 74 ± 5 yrs Female Healthy elderly	10 weeks 3 d per week	Supervision not reported Weight machines 3 sets of 8 reps at 8RM	Baseline and 10 weeks	
Fatouros et al. 2005	Greece	RT low intensity = 71.1 ± 3.6 yrs RT mod intensity = 69.7 ± 3.8 yrs RT high intensity = 70.8 ± 2.8 yrs CON = 69.8 ± 5.1 yrs Male Sedentary obese	24 weeks 3 d per week	Supervised Weight machines and body weight RT low intensity – 1-8 weeks: 2 sets, 9-24 weeks: 3 sets, 45-50% 1RM RT mod intensity – 1-8 weeks: 2 sets, 9-24 weeks: 3 sets, 60-65% 1RM RT high intensity – 1-8 weeks: 2 sets, 9-24 weeks: 3 sets, 80-85% 1RM	Baseline and 24 weeks Follow up at 48 weeks	
Fenkci et al. 2006	Turkey	RT = 44 ± 10.2 yrs AT = 41.7 ± 6.9 yrs CON = 43.8 ± 7.4 yrs Female Sedentary obese	12 weeks 3 d per week	Supervision not reported Weight machines 1 week: 1 set of 10 reps of 40-60% 1RM 2 weeks: 2 sets of 10 reps of 40-60% 1RM 3 weeks: 3 sets of 10 reps of 40-60% 1RM 4-12 weeks: 3 sets of 75-80% 1RM	Baseline and 12 weeks	
Figueroa et al. 2012 Figueroa et al. 2013 Figueroa et al. 2013	USA	Not reported. RT with WBV = 56 ± 3 yrs CON = 56 ± 3 yrs RT with WBV = 55.5 ± 0.7 yrs CON = 56.4 ± 1 yrs Female Sedentary obese	6 weeks 12 weeks 3 d per week	Supervised Whole body vibration with free weights Vibration intensity was progressed by increasing the frequency (25–30Hz) and amplitude (1–2mm). The duration of the sets and rest periods was progressively increased (30–60 s) and decreased (60–30 s), respectively.	Baseline and 6 weeks	
Franklin et al. 2015	USA	RT = 30.3 ± 5.4 yrs CON = 30.8 ± 9.0 yrs Female Sedentary obese	8 weeks 2 d per week	Supervised Free weights and machines 2-3 sets of 10 reps at 80–90% 10RM	Baseline and 8 weeks	Supported by the National Heart, Lung, and Blood Institute grants IK23HL85614, RO1HL095701, and HL095701-01A2S, and the University of

						Illinois at Chicago, Centre for Clinical and Translational Science, award UL1RR029879 from the National Centre for Research Resources.
Garcia-Lopez et al. 2007	Finland	RT = 54.9 ± 1.9 yrs AT = 53.6 ± 2.4 yrs CON = 53.3 ± 2.5 yrs Male Healthy sedentary	21 weeks 2 d per week	Supervised Weight machines 1-7 weeks: 2-4 sets of 8-15 reps at 40–70% 1RM 8–14 weeks: 2-5 sets of 5-12 reps at 60–80% 1RM 15-21 weeks:3-5 sets of 5-10 reps at 60–85% 1RM	Baseline, 10.5 (not control group) and 21 weeks	Funded, in part, by a grant from the Ministry of Education, Finland.
Gater et al. 1992	USA	Physically active	10 weeks	Not reported	Baseline and 10 weeks	Grant from Ross Laboratories, the Achievement Reward for College Scientists Foundation, and National Heart, Lung and Blood Institute Research Services Award HL-07249.
Gelecek et al. 2012	Turkey	RT = 54.3 ± 5.3 yrs CON = 51.8 ± 3.7 yrs Female Post-menopausal	12 weeks 3 d per week	Supervised Free weights and machines 2 sets of 8-12 reps at 60% 1RM	Baseline and 12 weeks	Funded by the Department of Scientific Research Projects of Dokuz Eylül University.
Gettman et al. 1978	USA	Physically active	20 weeks 3 d per week	Supervision not reported Free weight, weight machines and body weight 1-6 weeks: 10-20 reps per set at 50% 1RM 7-20 weeks: 15 reps per set at 50% 1RM	Baseline and 20 weeks	Supported by the International Association of Chiefs of Police/Law Enforcement Assistance Administration, Grant No. 76-NI-99-001
Gordon et al. 2006	UK	RT = 67 ± 2 yrs CON = 67 ± 2 yrs Male and female Type 2 diabetes	16 weeks 3 d per week	Supervision not reported Weight machines 3 sets of 8 reps at 60-65% 1RM	Baseline and 16 weeks	Supported by the Brookdale Foundation, USDA ARS Cooperative Agreement 58-1950-9-00 I and NIH GCRC grant MOI RR000054.
Greenwood et al. 2015	USA	RT = 54.6 ± 10.6 yrs AT = 53.9 ± 10.7 yrs CON = 49.5 ± 10.6 yrs Male and female Kidney transplant recipients	12 weeks 3 d per week	Supervised Elastic resistance bands, ankle weights and free weights 1-2 sets of 10 reps at 80% 1RM	Baseline and 12 weeks	Funded by an NIHR Doctoral Research Fellowship. The study was hosted in the King's College Hospital NIHR clinical research facility. This article presents independent research funded by the NIHR.
Gregory et al. 2013	USA	Total cohort = 20.3 ± 0.3 yrs Female Physically active	8 weeks 3 d per week	Supervised Free-weight, machine and body weight exercises 3 sets of 3-12RM	Baseline, 4 and 8 weeks	Grant from the U.S. Army Medical Research and Materiel Command Bone Health and Military Medical Readiness Research Program to BCN.

Hagberg et al. 1989	USA	Total cohort = 72 ± 3 yrs Male and female Healthy sedentary	26 weeks 3 d per week	Supervised Weight machines 8-12 reps	Baseline, 13 (not controls and 26 weeks	Funded, in part, by a grant from the Diabetes Treatment Centres of America Foundation.
Hagerman et al. 2000	UK	RT = 63.7 ± 5 yrs CON = 66.2 ± 6.5 yrs Male Healthy elderly	16 weeks 2 d per week	Supervision not reported Free-weight, machine and body weight exercises 1 set of 10 reps at 85-90% 1RM followed by 3 sets to failure of 6-8 reps at 85-90% 1RM	Baseline and 16 weeks	
Hagstrom et al. 2016	Australia	RT - 51.2 ± 8.5 yrs CON - 52.7 ± 9.4 yrs Female Breast cancer	16 weeks 3 d per week	Supervised Free weight and weight machines 3 sets of 8-10 reps at 8RM	Baseline and 16 weeks	Supported by a grant from Western Sydney University, Australia.
Hallsworth et al. 2011 Jakovljevic et al.	Finland	RT = 52 ± 13.3 yrs CON = 62 ± 7.4 yrs RT = 49 ± 13 yrs CON= 62 ± 7 yrs Male and female Non-alcoholic fatty liver disease	8 weeks 3 d per week	Supervision biweekly Free weights and weight machine 2 sets at 50% 1RM	Baseline and 8 weeks	
Hautala et al. 2006	Canada	RT = 42 ± 1 yrs CON = 41 ± 1 yrs Male and female Healthy sedentary	2 weeks 5 d per week	Supervised 1 set of 8-12 reps	Baseline and 2 weeks	Funding from the EU Seventh Framework Programme (FP7/2007-2013) under grant agreement no Health-F2-2009-241762, for the project FLIP; the MRC; the UK NIHR Biomedical Research Centre on Ageing and Age-Related Diseases and Diabetes UK.
Haykowsky et al. 2000	Canada	RT = 68 ± 3 yrs CON = 68 ± 4 yrs Male Healthy elderly	16 weeks 3 d per week	Supervision not reported Free weights and weight machine 3-10 reps at 60-80% 1RM	Baseline, 4, 8, 12 and 16 weeks	Grants from the Ministry of Education (Helsinki, Finland) and the Medical Council of the Academy of Finland (Helsinki, Finland).
Haykowsky et al. 2005	Iran	RT = 70 ± 4 yrs AT = 66 ± 3 yrs Combined = 68 ± 6 yrs CON = 67 ± 4 yrs Female Healthy elderly	12 weeks 3 d per week	Supervised 2 sets of 10 reps at 50% 1RM	Baseline and 12 weeks	
Hedayati et al. 2012	USA	RT 40% 1RM = 23.2 ± 1 yrs RT 80% 1RM = 21.9 ± 1.5 yrs CON = 20.8 ± 1 yrs	4 weeks 4 d per week	Supervision not reported Free weights and machines 3 sets of 8-11 reps	Baseline and 4 weeks	

		Female Physically active				
Heffernan et al. 2013	USA	RT = 60 ± 2 yrs CON = 63 ± 2 yrs Sex not reported. Pre-hypertensive and newly diagnosed/never-treated hypertensive	12 weeks 3 d per week	Supervised Weight machines 2 sets of 12-15 reps at 40% 1RM for upper body and 60% 1RM for lower body	Baseline and 12 weeks	
Hendrickson et al. 2010	USA	RT = 21 ± 0.5 yrs AT = 21 ± 0.4 yrs Combined = 20 ± 0.4 yrs CON = 20 ± 0.5 yrs Female Physically active	12 weeks 3 d per week	Supervised Free weights, machine and body weight exercises 3–6 weeks - ‘‘light’’ days at 12RM, ‘‘moderate’’ days at 8–10RM, and ‘‘heavy’’ days at 6–8RM loads. 8–11 weeks - ‘‘light’’ days at 12RM, ‘‘moderate’’ days at 6–8RM, and ‘‘heavy’’ days at 3–5RM	Baseline and 12 weeks	
Hiatt et al. 1994 Hiatt et al. 1996	Finland	RT = 67 ± 6 yrs AT = 67 ± 7 yrs CON = 67 ± 5 yrs Male Peripheral artery disease	12 weeks 4 d per week 3 d per week	Supervised Cuff weight secured to the leg 3 sets or 6RM	Baseline and 12 weeks	Funded, in part, by a grant from the Medical Research and Material Command Bone Health Research Program to BCN.
Hoff et al. 2007	Norway	RT = 62.8 ± 1.4 yrs CON = 60.6 ± 3.0 yrs Male and female Chronic obstructive pulmonary disease	8 weeks 3 d per week	Supervision not reported 4 sets of 5 reps at 85-90% 1RM	Baseline and 8 weeks	Grant H133G90114 from the National Institute on Disability and Rehabilitation Research. Dr Hiatt is the recipient of a National Institutes of Health Academic Award in Vascular Disease.
Holviala et al. 2012	Belgium	RT = 56.5 ± 7.6 yrs AT = 55.5 ± 8.7 yrs Combined = 56.9 ± 7.5 yrs CON = 56.7 ± 7.5 yrs Male Healthy sedentary	21 weeks 2 d per week	Supervised Weight machines 1-7 weeks - 40–60% of 1RM 8-14 weeks - 60–80% of 1RM 15-21 weeks - 70–85% of the 1RM	Baseline and 21 weeks	
Hoof et al. 1996	Canada	Age not reported. Male Healthy sedentary	16 weeks 3 d per week	Supervised Weight machines 1-4 weeks – 3 sets of 12 reps at 70%1RM 5-16 weeks - 3 sets of 10 reps at 70% 1RM followed by 4 reps at 90% 1RM	Baseline and 16 weeks	Funded, in part, by the Norwegian Research Council by providing a Professor II position for Dr Richardson, grant HL-17731 from the National Heart, Lung, and Blood Institute and Tobacco Related Disease Research Program grant #15RT-0100.

Horne et al. 1996	Finland	Total cohort = 22.3 ± 3.3 yrs Male and female Physically active	12 weeks 3 d per week	Supervision not reported Machines and free weights	Baseline, 6 and 12 weeks	Grants from the Belgian Ministry of Defence.
Hu et al. 2009	USA	RT = 32.2 ± 7.2 yrs CON = 31 ± 7.5 yrs Males Healthy sedentary	10 weeks 2-3 d per week	Supervised	Baseline and 10 weeks	
Huffman et al. 2014	Norway	Age not reported. Male and female Metabolic risk factors	24 weeks 3 d per week	Supervised Weight machines 3 sets of 8-12 reps	Baseline and 24 weeks	Grants from the National Technology Agency of Finland, the Ministry of Education of Finland, Juho Vainio Foundation and partially funded by the National Science Foundation of Guangdong Province (815100760100004), China.
Husby et al. 2009 Husby et al. 2010	USA	RT = 58 ± 5 yrs CON = 56 ± 8 yrs Male and female Total hip arthroplasty	4 weeks post-operative 5 d per week	Supervised Weight machines 4 sets of 5 reps at 85% 1RM	Pre-operative, 1 week post-operative, 5 week Follow up at 24 and 52 weeks	Supported by the National Heart, Lung, and Blood Institute, National Institute on Aging and National Institute of Arthritis and Musculoskeletal and Skin Diseases.
Irving et al. 2015	Denmark	Young: RT = 25 ± 1 yrs AT = 25 ± 1 yrs CON = 26 ± 1 yrs Combined = 26 ± 1 yrs Old: RT = 70 ± 1 yrs AT = 70 ± 1 yrs CON = 71 ± 2 yrs Combined = 71 ± 2 yrs Male and female Healthy sedentary	8 weeks 4 d per week	Supervised 4 sets of 8–10 reps	Baseline and 8 weeks	Supported by National Institute of Health grant R01-AG09531, RO1-DK41973, National Centre for Advancing Translational Science grants UL1-RR024150 and KL2-RR024151, CTSA Grant Number UL1- TR000135 from the National Centre for Advancing Translational Sciences a component of the National Institutes of Health.
Jay et al. 2011	Finland	RT = 44 ± 8 yrs CON = 43 ± 10 yrs Male and female Healthy sedentary	8 weeks 3 d per week	Supervised Kettlebells	Baseline and 8 weeks	Funded by The National Research Centre for the Working Environment.
Kaikkonen et al. 2000	Brazil	RT = 42.5 ± 7 yrs AT = 41.6 ± 6 yrs CON = 41.9 ± 7 yrs Male and female Healthy sedentary	12 weeks 3 d per week	No supervision provided Weight machines 3 circuits of 10 stations	Baseline and 12 weeks	

Kanegusuku et al. 2011	Finland	RT = 63 ± 1 yrs Power Training = 65 ± 1 yrs CON = 63 ± 1 yrs Male Healthy elderly	16 weeks 2 d per week	Supervision not reported Weight machines RT: 2 sets, 10 reps at 70% to 4 sets, 4-6 reps, 85-90% PT: 3 sets, 7 reps, 30% to 4 sets, 4-6 reps, 45-50%	Baseline and 16 weeks	Supported by FAPESP (#07/56653-1 and #07/00788-6), CNPq (#471600/2008-3), CAPES, and Head of the Psychopharmacology Incentive Fund Association.
Karavirta et al. 2009 Karavirta et al. 2011	Finland	RT = 56 ± 6 yrs AT = 54 ± 8 yrs Combined = 56 ± 7 yrs CON = 54 ± 8 yrs Male Healthy sedentary	21 weeks 2 d per week	Supervised Weight machines and body weight 1-7 weeks: 3 sets of 15-30 reps at 40–60% 1RM 8-14 weeks: 2-4 sets of 6-12 reps at 60–80% 1RM 15-21 weeks: 2-4 sets of 5-8 reps at 70–85% 1RM	Baseline, 10.5 and 21 weeks	Partially supported by grants from the Ministry of Education, Finland, Central Finland Health Care District, Jyväskylä, Finland, and Polar Electro Oy. Partly supported by the Ministry of Education, Finland and the Juho Vainio Foundation, Finland.
Karavirta et al. 2013	Japan	RT = 52 ± 8 yrs AT = 52 ± 7 yrs Combined = 49 ± 6 yrs CON = 52 ± 8 yrs Female Healthy sedentary	21 weeks 2 d per week	Supervised Weight machines and body weight 1-7 weeks: 3 sets of 12-20 reps at 40–60% 1RM 8-14 weeks: 2-4 sets of 5-12 reps at 60–80% 1RM 15-21 weeks: 2-4 sets of 5-8 reps at 70–85% 1RM	Baseline, 10.5 and 21 weeks	Partly supported by the grants from the Ministry of Education and Culture, Central Finland Health Care District, Juho Vainio Foundation, Yrjo Jahnsson Foundation, the University of Jyväskylä, G. Harold and Leila Y. Mathers Charitable Foundation, James S. McDonnell Foundation, the National Institutes of Health-sponsored Research Resource for Complex Physiologic Signals, and the National Institute on Aging.
Karelis et al. 2015	Canada	RT - 45. 3± 14 yrs CON - 39.4 ± 8 yrs Male and female Kidney transplant patients	16 weeks 3 d per week	Supervised for 1 session a week Free weight, weight machines, body weight and elastic resistance 3 sets of 10 reps at 80% 1RM	Baseline and 16 weeks	Supported by funds from investigator-sponsored research by AstellasPharma Canada, Inc (SG112). RRL is supported by the Fonds de Recherche du Québec - Santé and holds the J-A De Sève research chair. MJH is supported by the Canadian Institutes of Health Research and Canadian National Transplant Research Program and holds the Shire chair in nephrology and renal transplantation and regeneration at the Université de Montréal.

Kawano et al. 2006	Canada	RT = 20 ± 1 yrs Combined = 21 ± 1 yrs CON = 22 ± 1 yrs Male Healthy sedentary	20 weeks 3 d per week	Supervised Free weights, weight machines and body weight 3 sets at 50%1 RM	Baseline, 8 and 12 weeks Follow up at 24 and 32 weeks	Grants from the Ministry of Health, Labour and Welfare (H18-J-W-002), Japan Society for the Promotion of Science (17300226), and the National Institutes of Health in the US (AG20966).
Kell & Asmundson 2009	UK	RT = 40.1 ± 8.7 yrs AT = 36.7 ± 8.9 yrs CON = 35.3 ± 7.3 yrs Male and female Chronic lumbar pain	16 weeks 3 d per week	Supervised Free weights, weight machines and body weight 4 sets of 10 reps at 53–72% 1RM	Baseline, 8 (not controls) and 16 weeks	Support from the Saskatchewan Health Research Foundation (New Investigator Grant) and the University of Alberta, Augustana Campus (travel grant).
Kemi et al. 2011	Iran	RT = 20.8 ± 2.4 yrs CON = 23 ± 2.9 yrs Female Healthy sedentary	8 weeks 3 d per week	Supervised Free weights 5 sets of 5 reps at 85% 1RM	Baseline and 8 weeks	
Kemmler et al. 2016	Germany	HIT = 42.9 ± 5.4 yrs CON = 42.5 ± 5.6 yrs Male Healthy sedentary	22 weeks 2-3 d per week	Supervised Weight machines Single set to failure of 6-8 reps	Baseline and 22 weeks	The authors are grateful for the support of the Staedtler-Stiftung (Nürnberg, Germany), Kieser Training (Erlangen, Germany), Post SV Nürnberg (Nürnberg, Germany), and Protein4you (Saarlouis, Germany).
Khorvash et al. 2012	USA	Total cohort = 25.1 ± 3.2 yrs Male Depression and anxiety	10 weeks 2 d per week	Supervision not reported Free weights, weight machines and body weight	Baseline and 10 weeks	
Kim et al. 2011	Switzerland	Traditional RT = 20.8 ± 0.8 yrs Super slow RT = 19.5 ± 0.3 yrs CON = 21.5 ± 0.8 yrs Female Healthy sedentary	4 weeks	Supervision not reported Weight machines Traditional RT: 3 sets of 8 reps at 80% 1RM Super slow RT: 1 set to fatigue at 50% 1RM	Baseline and 4 weeks	
Kriemler et al. 2013	Korea	RT = 19 yrs AT = 23.8 yrs CON Swiss = 20.3 yrs CON German = 19.5 yrs Male and female Cystic fibrosis	24 weeks 3 d per week	Supervision for 1 session a week 1 set of 6-9 reps at 10RM	Baseline, 12 and 24 weeks Follow up at 52 and 104 weeks	Grant from the Swiss CF Foundation and the German Mukoviszidose e.V.
Ku et al. 2010	Korea	RT = 55.7 ± 6.2 yrs AT = 55.7 ± 7 yrs CON = 57.8 ± 8.1 yrs Female Type 2 diabetes	12 weeks 4 d per week	Supervised Elastic resistance bands 3 sets of 15-20 reps	Baseline and 12 weeks	

Kwon et al. 2010	Korea	RT = 55.7 ± 6.2 yrs CON = 57 ± 8 yrs Female Type 2 diabetes	12 weeks 3 d per week	Supervision not reported Elastic resistance bands 3 sets of 10-15 reps	Baseline and 12 weeks	Supported by Korean Diabetes Clinical Research Institution.
Kwon et al. 2011	Canada	RT = 56.3 ± 6.1 yrs AT = 55.5 ± 8.6 yrs CON = 58.9 ± 5.7 yrs Female Type 2 diabetes	12 weeks 3 d per week	Supervision not reported Elastic resistance bands 3 sets of 10-15 reps	Baseline and 12 weeks	
Larose et al. 2010	USA	RT = 54.7 ± 7.5 yrs AT = 53.9 ± 6.6 yrs Combined = 53.5 ± 7.3 yrs CON = 54.8 ± 7.2 yrs Male and female Type 2 diabetes	Run in of 4 weeks followed by 22 weeks intervention. 2-3 d per week	Supervised Biweekly supervision after week 4 Weight machines 4 week run-in phase: 1-2 sets of 10 reps 5-22 weeks: 3 sets of 8 reps	Baseline and 22 weeks	Grants from the Canadian Institutes of Health Research (grant MCT-44155), Canadian Diabetes Association (The Lillian Hollefriend Grant), and the Interfaculty Grant program of the University of Ottawa.
LeMura et al. 2000	Australia	RT = 20 ± 1 yrs AT = 21 ± 2 yrs Cross training = 19 ± 2 yrs CON = 20 ± 1 yrs Female Healthy sedentary	16 weeks 3 d per week	Supervised Free weights, weight machines and body weight 1-2 weeks: 1 set of 8-10 reps at 60-70% 1RM 3-14 weeks: 3 sets of 8-10 reps at 60-70% 1RM	Baseline, 8 and 16 weeks Follow up at 20 weeks	
Levinger et al. 2007 Levinger et al. 2008 Levinger et al. 2009	Brazil	LoMFC = 48.5 ± 7.7 yrs LoMFT = 50.6 ± 5.1 yrs HiMFC = 52.3 ± 5.8 yrs HiMFT = 51.6 ± 7.1 yrs LoMFC = 48.9 ± 7.4 yrs LoMFT = 50.3 ± 4.1 yrs HiMFC = 51.9 ± 5.8 yrs HiMFT = 51 ± 7 yrs LoMFC = 48.5 ± 7.7 yrs LoMFT = 50.6 ± 5.1 yrs HiMFC = 52.3 ± 5.8 yrs HiMFT = 51.6 ± 7.1 yrs Male and female Metabolic risk factors	10 weeks 3 d per week	Supervised Weight machines Week 1: 2 sets of 15–20 reps at 40–50% 1RM Week 2: 3 sets of 15–20 reps at 50–60% 1RM 3-6 weeks: 3 sets of 12–15 reps at 60–75% 1RM 7-10 weeks: 3 sets 8 –12 reps at 75–85% 1RM	Baseline and 10 weeks	
Libardi et al. 2011 Libardi et al. 2012	Taiwan	RT = 48.6 ± 5 yrs Concurrent = 48.5 ± 5.3 yrs CON = 49.1 ± 5.5 yrs Male Healthy sedentary	16 weeks 3 d per week	Supervision not reported Free weights, weight machines and body weight 3 sets at 8-10RM	Baseline and 16 weeks	Supported by the National Council of Technological and Scientific Development, Brazil. Supported by the National Counsel of Technological and Scientific Development, Brazil.

		RT = 49.3 ± 4.8 yrs AT = 49.3 ± 5.4 yrs Concurrent = 48.5 ± 5.4 yrs CON = 49.1 ± 5.9 yrs Male Healthy sedentary				
Lo et al. 2011	Australia	RT = 20.2 ± 1.4 yrs AT = 20 ± 0.7 yrs CON = 21.1 ± 1.7 yrs Male Healthy sedentary	24 weeks 3 d per week	Supervised Weight machines 1-8 weeks: 1 set at 15RM 9-16 weeks: 1 set of 10 reps at 75% 1RM 17-24 weeks: 2 sets of 4 reps at 90% 1RM	Baseline and 24 weeks Follow- up at 48 weeks	Supported by the National Science Council, 95-2413-H-006-010, Taiwan, ROC.
Lovell et al. 2009 Lovell et al. 2012	USA	RT = 74.1 ± 2.7 yrs CON = 73.5 ± 3.3 yrs RT = 74.1 ± 2.7 yrs AT = 75.2 ± 3.0 yrs CON = 73.5 ± 3.3 yrs Male Healthy elderly	16 weeks 3 d per week	Supervised Weight machine 3 sets of 6-10 reps at 50-90%1RM	Baseline, 4, 8, 12, and 16 weeks	
Madden et al. 2006	Iran	RT = 69.8 ± 1.5 yrs AT = 70 ± 2.6 yrs CON = 71.8 ± 1.2 yrs Female Healthy elderly	24 weeks 5 d per week	Supervised Free weights 3 sets of 8-12 reps at 85% 1RM	Baseline and 24 weeks	Supported by the AHA Washington Affiliate Grant-in-aid, the Medical research service of the department of veterans affairs
Mahdirejei et al. 2014	Australia	RT = 47.6 ± 7.7 yrs CON = 49.6 ± 8.1 yrs Male Type 2 diabetes	8 weeks 3 d per week	Supervised Free weights, weight machines and body weight 3 sets of 8-15 reps at 50-80% 1RM	Baseline and 8 weeks	Supported by Islamic Azad University Sari Branch, Sari, Iran.
Maiorana et al. 1997	Australia	RT = 61.2 ± 8.4 yrs CON = 59 ± 8.7 yrs Male Coronary bypass graft	10 weeks	Supervised Free weights, weight machines and body weight 1-3 sets of 10-15 reps at 40-60% MVC	Baseline and 10 weeks	
Maiorana et al. 2011	USA	RT = 58.8 ± 3.5 yrs AT = 61.3 ± 2.8 yrs CON = 64.4 ± 2.4 yrs Male and female Stable chronic heart failure	12 weeks 3 d per week	Supervised Free weights, weight machines and body weight 1-6 weeks: 3 sets of 60 secs at 50-60% 1RM 7-12 weeks: 3 sets of 60 secs at 60-70% 1RM	Baseline, 6 and 12 weeks	Supported by the National Heart Foundation (Australia), the Dutch Heart Foundation (E. Dekker, stipend) and the Australian Research Council.
Malin et al. 2013	USA	Normal body fat = 21.9 ± 0.8 yrs High body fat = 21.0 ± 0.8 yrs CON = 20.9 ± 0.6 yrs	7 weeks 3 d per week	Supervised Free weights, weight machines and body weight 3 sets of 10-12 reps at 60% 1RM	Baseline and 7 weeks	Funded by the Wayne State College Foundation.

		Female Healthy sedentary				
Manning et al. 1991	USA	RT= 35.4 ± 2.6 yrs CON = 40.3 ± 5.5 yrs Female Sedentary obese	12 weeks 3 d per week	Supervision not reported Free weights and weight machines 2-3 sets of 6-8 reps at 60-70% 1RM	Baseline, 4, 8 and 12 weeks	Supported, in part, by grant from the Valley Hospital and the William Paterson College of New Jersey.
Marcinik et al. 1991	USA	RT= 29 ± 4 yrs CON = 30 ± 4 yrs Male Healthy sedentary	12 weeks 3 d per week	Supervised Free weights, weight machines and body weight 3 sets at 8-20RM	Baseline and 12 weeks	
Marcus et al. 2009	Portugal	RT Eccentric = 56.3 ± 6.4 yrs CON = 53.2 ± 6.5 yrs Females Impaired glucose tolerance	12 weeks 3 d per week	Supervised Weight machine	Baseline and 12 weeks	Supported by the Utah Building Interdisciplinary Research Careers in Women's Health Program (NIH grant 5K12HD043449-04).
Martins et al. 2010 Martins et al. 2010	USA	Total cohort = 76 ± 8 yrs Male and female Healthy sedentary RT= 73.2 ± 6.5 yrs AT = 76.2 ± 7.4 yrs CON = 81.2 ± 7.9 yrs Males and females	16 weeks 3 d per week	Supervised Elastic resistance bands 1-2 weeks: 1 set of 8 reps 3-4 weeks: 1 set of 12 reps 5-6 weeks: 2 sets of 8 reps 7-8 weeks: 2 sets of 10 reps 9-10 weeks: 2 sets of 12 reps 11-12 weeks: 2 sets of 15 reps 13-14 weeks: 3 sets of 12 reps 15-16 weeks: 3 sets of 15 reps	Baseline and 16 weeks Baseline and 16 weeks Follow-up at 32 weeks	Supported by the Portuguese Foundation for Science and Technology and the Portuguese Institute of Sport.
McDermott et al. 2009	Australia	RT = 71.7 ± 8.7 yrs AT = 71.7 ± 8.7 yrs CON = 68.5 ± 11.9 yrs Male and female Peripheral artery disease	24 weeks 3 d per week	Supervised Weight machines 3 sets of 8 reps at 50-80% 1RM	Baseline and 24 weeks	Supported by grants R01-HL073551 from the National Heart, Lung, and Blood Institute and by RR-00048, National Institutes of Health and the Intramural Research Program, National Institutes on Aging.
McGuigan et al. 2001	USA	RT = 70 ± 6 yrs CON = 66 ± 6 yrs Male and female Peripheral artery disease	24 weeks 3 d per week	Supervised Free weights, weight machines and body weight 2 sets at 8-15RM	Baseline, 12 and 24 weeks	Supported by an American College of Sports Medicine Foundation Research Grant for doctoral students.
Mikesky et al. 1994	Canada	RT= 69.2 ± 4.0 yrs CON = 72.8 ± 5.7 yrs Male and female Healthy elderly	12 weeks 3 d per week	Supervision for 1 session a week Body weight and elastic resistance bands 1-2 weeks: 1 set of 12 reps 3-4 weeks: 2 sets of 12 reps 5-12 weeks: 2-3 sets of 12 reps	Baseline and 12 weeks	Grant from the Indiana University Grant-in-Aid program.
Millar et al. 2008	Japan	RT = 66 ± 1 yrs CON = 67 ± 2 yrs Male and female Healthy elderly	8 weeks 3 d per week	Supervision for 2 sessions a week Weight machine 1 set of 4 reps at 30-40% MVC	Weekly for 8 weeks	Supported by an Ontario Graduate Scholarship award and a Natural Sciences and

						Engineering Research Council of Canada Discovery grant.
Miura et al. 2008	Japan	RT 1d·week = 69 ± 6.5 yrs RT 2d·week = 69.5 ± 7 yrs CON = 68.9 ± 7.5 yrs Female Healthy elderly	12 weeks 1 or 2 d per week	Supervised Free weights and elastic resistance bands 3–5 sets of 15–20 reps	Baseline and 12 weeks	Supported by a Grant-in Aid for Scientific Research from the Ministry of Education, Science, Sports and Culture of Japan (15700441).
Miyachi et al. 2004	Norway	RT = 22 ± 1 yrs CON = 22 ± 1 yrs Male Healthy sedentary	16 weeks 3 d per week	Supervised Free weights, weight machines and body weight 3 sets of 12 reps at 80% 1RM	Baseline and 16 weeks Follow-up at 24 weeks	Grants from the National Institutes of Health (AG-020966), Japan Society for Promotion of Science (13780041 and 14208005) and the Meiji Yasuda Life Foundation.
Mosti et al. 2013	Norway	RT = 61.9 ± 5 yrs CON = 66.7 ± 7.4 yrs Females Osteoporosis or osteopenia	12 weeks 3 d per week	Supervised Weight machines 4 sets of 3–5 reps at 85–90% 1RM	Baseline and 12 weeks	Funded by the Liaison Committee between the Central Norway Regional Health Authority and the Norwegian University of Science and Technology.
Mosti et al. 2014	Brazil	RT= 22.7 ± 2.2 yrs CON = 21.5 ± 2.2 yrs Female Healthy sedentary	12 weeks 3 d per week	Supervised Weight machines 4 sets of 3–5 reps at 85–90% 1RM	Baseline and 12 weeks	Corresponding author funded by a PhD grant from the Liaison Committee between the Central Norway Regional Health Authority and the Norwegian University of Science and Technology.
Mota et al. 2013	Iran	RT = 67.5 ± 7 yrs CON = 66.8 ± 5.4 yrs Female Hypertensive	16 weeks 3 d per week	Supervised Free weights and weight machines 1-4 weeks: 3 sets of 10 reps 5-8 weeks: 3 sets of 12 reps at 60% 1RM 9-12 weeks: 3 sets of 10 reps at 70% 1RM 13-16 weeks: 3 sets of8 reps at 80% 1RM	Baseline, 4, 8, 12 and 16 weeks	
Nikseresht et al. 2014 Nikseresht et al. 2014	Denmark	RT non-linear = 40.4 ± 5.2 yrs AT = 39.6 ± 3.7 yrs CON = 38.9 ± 4.1 yrs RT non-linear = 40.4 ± 5.2 yrs AT = 39.6 ± 3.7 yrs Lean = 39 ± 5.9 yrs CON = 38.9 ± 4.1 yrs Male Sedentary obese	12 weeks 12 weeks training. 4 weeks detraining period 3 d per week	Supervised Free weights and weight machines 1-4 sets of 2-20 reps at 40-95% 1RM	Baseline and 12 weeks Baseline, 12 weeks and follow-up	None reported. Grants from the Ilam University of Medical Sciences, Ilam, Iran.

Nybo et al. 2010	Japan	RT = 36 ± 2 yrs Interval running = 37 ± 3 yrs Prolonged running = 31 ± 2 yrs CON = 30 ± 2 yrs Male Healthy sedentary	12 weeks 3 d per week	Supervision not reported Free weights and weight machines 1-4 weeks: 4 sets of 12-16RM 5-12 weeks: 4 sets at 6-10RM	Baseline and 12 weeks	Supported by the Danish Ministry of Culture (Kulturministeriets Udvalg for Idrætsforskning).
O'Connor et al. 2017	UK	RT - 54.6 ± 10.6 yrs CON - 49.5 ± 10.6 yrs Male Kidney transplant recipients	12 weeks 3 d per week	Supervision for 2 sessions a week Free weights, weight machines and body weight 1-3 sets of 10 reps at 80% 1RM	Baseline and 12 weeks	Funded by the NIHR. The study was hosted in the KCH NIHR Clinical Research Facility. This paper presents independent research funded by the NIHR.
Okamoto et al. 2006	Japan	RT Eccentric = 18.9 ± 0.3 yrs RT Concentric 19.1 ± 0.3 yrs CON = 19.9 ± 1.2 yrs Female Healthy sedentary	8 weeks 3 d per week	Supervised Free weights 5 sets of 8-10 reps 80-100% 1RM	Baseline and 8 weeks Follow-up (unclear duration)	
Okamoto et al. 2009a	Japan	RT Eccentric = 19.6 ± 0.4 yrs RT Concentric = 19.2 ± 0.3 yrs CON = 19.7 ± 0.3 yrs Male Physically active	10 weeks 2 d per week	Supervision not reported Free weights, weight machines and body weight 5 sets of 8-10 reps at 80% 1RM	Baseline and 10 weeks	Partially supported by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Young Scientists (B), 19700539, 2007.
Okamoto et al. 2009b	Japan	RT Upper = 20.2 ± 0.4 yrs RT Lower = 20 ± 0.5 yrs CON = 20.1 ± 0.3 yrs Male and female Healthy sedentary	10 weeks 2 d per week	Supervised Free weights and weight machines 5 sets of 8-10 reps at 80% 1RM	Baseline and 10 weeks	
Okamoto et al. 2011	Japan	RT = 18.5 ± 0.5 yrs CON = 18.6 ± 0.5 yrs Male Healthy sedentary	10 weeks 2 d per week	Supervision not reported Free weights, weight machines and body weight 5 sets of 10 reps	Baseline and 10 weeks	Supported by the Grant-in-Aid for Scientists Research from the Ministry of Education, Culture, Sports, Science and Technology of Japan (21700680).
Okamoto et al. 2013	Norway	High then low intensity RT = 19.1 ± 0.7 yrs Low then high intensity RT = 19.3 ± 0.7 yrs CON = 19.1 ± 0.6 yrs Male and female Healthy sedentary	10 weeks 2 d per week	Supervision not reported Free weights and weight machines 3 sets of 10 reps to concentric failure	Baseline and 10 weeks	

Oldervoll et al. 2001	Brazil	RT = 42.2 ± 6 yrs AT = 42.6 ± 6 yrs CON = 43.9 ± 8.8 yrs Female Musculoskeletal pain	15 weeks 2 d per week	Supervision not reported 2-3 sets of 12-15 reps	Baseline and 15 weeks	Grant no. 111222/330 from the Norwegian Research Council and the University Hospital of Trondheim provided financial support for the employment of one of the instructors.
Oliveira et al. 2013	USA	RT = 22 ± 3 yrs CON = 23 ± 4 yrs Male Physically active	8 weeks 3 d per week	Supervised Isokinetic eccentric resistance exercise on weight machines 1-2 weeks: 2 sets of 8 reps 3-4 weeks: 4 sets of 8 reps 5-6 weeks: 6 sets of 8 reps 7-8 weeks: 3 sets of 8 reps	Baseline and 8 weeks	Supported by FAPESP and CNPq.
Olson 2006	Norway	RT = 38 ± 1 yrs CON = 38 ± 2 yrs Female Sedentary overweight	52 weeks 2 d per week	Supervised for the initial 16 weeks Free weights and weight machines 3 sets of 8–10 reps	Baseline and 52 weeks	Supported, in part, by the National Institutes of Health grant #:5R01DK060743-03, American Heart Association grant #:0410034Z and General Clinical Research Centre Program, NCRR/NIH #:M01-RR00400.
Osteras et al. 2002	USA	RT = 21 ± 1.6 yrs CON = 24.4 ± 5 yrs Male Cross country skiers	9 weeks	Supervision not reported Weight machines 3 sets of 6 reps at 85% 1RM	Baseline and 9 weeks	
Panton et al. 1990	South Africa	RT = 72.2 ± 2.5 yrs Walk/jog = 71.8 ± 1.9 yrs CON = 72.1 ± 3 yrs Male and female Healthy sedentary	26 weeks 3 d per week	Supervised Weight machines 1 set of 8-12 reps	Baseline and 26 weeks	
Parr et al. 2009	Spain	RT Upper = 66 ± 13 yrs Conventional Exercise Rehab = 57 ± 14 yrs CON = 62 ± 10 yrs Male and female Peripheral artery disease	6 weeks 3 d per week	Supervised Free weights and weight machines 15-30 reps	Baseline and 6 weeks	
Perez-Gomez et al. 2013	Canada	RT = 22 ± 1.2 yrs ET = 21.8 ± 1 yrs CON = 23.3 ± 2.5 yrs Male Physically active	10 weeks	Supervised Free weights and weight machines 50-90% of 1RM	Baseline and 10 weeks	
Plotnikoff et al. 2010	USA	RT = 55 ± 12 yrs CON = 54 ± 12 yrs Male and female Type 2 diabetes	16 weeks 3 d per week	Supervision tapered Free weights and weight machines Week 1: 2 sets of 10–12 reps at 50–60% 1RM	Baseline and 16 weeks	Funded by the Canadian Institutes of Health Research, Strategic Initiative in Excellence, Innovation and Advancement for

				Week 2: 3 sets of 10-12 reps at 50-60% 1RM 3-8 weeks: 3 sets of 10-12 reps, intensity progressively increase to 70-80% 1RM Week 9: 2 sets of 10–12 reps at 70% 1RM 10-15 weeks: 3 sets of 8–10 reps at 70–85% 1RM Week 16: 2 sets of 8–10 reps at 80% 1RM.		the Study of Obesity and Healthy Body Weight.
Poehlman et al. 2000	USA	RT = 28 ± 3 yrs AT = 29 ± 5 yrs CON = 28 ± 4 yrs Female Healthy sedentary	24 weeks 3 d per week	Supervised Free weights, weight machines and body weight 3 sets of 10 reps	Baseline and 6 week	Grant from the Department of Defence (DE-950226), a post-doctoral fellowship from the American Heart Association, Maine/New Hampshire/Vermont affiliate, a grant from the Medical Research Council of Canada, and General Clinical Research Centre Grant RR-109.
Poehlman et al. 2002	USA	RT = 28 ± 3 yrs AT = 28 ± 4 yrs CON = 28 ± 4 yrs Female Healthy sedentary	24 weeks 3 d per week	Supervised Free weights, weight machines and body weight 3 sets of 10 reps	Baseline and 6 weeks	
Pollock et al. 1991	USA	RT = 72.2 ± 2.5 yrs Walk/Jog = 71.8 ± 1.9 yrs CON = 72.1 ± 3 yrs Male and female Healthy elderly	26 weeks 3 d per week	Supervision not reported Weight machines 1 set of 10-12 reps	Baseline and 26 weeks	
Prabhakaran et al. 1999	USA	RT = 28 ± 6 yrs CON = 26 ± 6 yrs Female Healthy sedentary	14 weeks 3 d per week	Supervised Free weights and weight machines 85% 1RM	Baseline and 24 weeks	Funded by the Yamanaka Fund.
Rana et al. 2008	USA	RT = 20.6 ± 1.9 yrs RT Low Velocity = 19.4 ± 1.3 yrs AT = 22.3 ± 3.9 yrs CON = 22.9 ± 2.4 yrs Female Healthy sedentary	6 weeks week 1 - 2 sessions weeks 2-6 - 3 days a week	Supervised Weight machines 3 sets at 6-10RM	Baseline and 6 weeks	
Roberts et al. 2013	Sweden	Male Sedentary obese	12 weeks 3 d per week	Supervised Free weights, weight machines and body weight 1–2 weeks: 2 sets of 12–15 reps 100% 12-15RM 3–7 weeks: 3 sets of 8–12 reps at 100% 8–12RM	Baseline and 12 weeks	Supported by the American Heart Association (BGIA # 0765139Y), the National Heart, Lung and Blood Institute (P50 HL105188), the National Institute of Diabetes and Digestive and Kidney Diseases

				8–12 weeks: 6–8 reps at 100% 6–8RM		(DK090406) and the National Centre for Advancing Translational Sciences through UCLA CTSI Grant UL1TR000124.
Rodriguez-Miguelez et al. 2014	Spain	RT = 69.1 ± 1.1 yrs CON = 70 ± 0.9 yrs Male and female Healthy elderly	8 weeks 2 d per week	Supervision not reported Weight machines Week 1: 3 sets of 8 reps at 60% 1RM Week 2: 3 sets of 10 reps at 60% 1RM Week 3: 3 sets of 12 reps at 60% 1RM Week 4: 3 sets of 8 reps at 70% 1RM Week 5: 3 sets of 10 reps at 70% 1RM Week 6: 3 sets of 12 reps at 70% 1RM Week 7: 3 sets of 8 reps at 80% 1RM Week 8: 3 sets of 10 reps at 80% 1RM	Baseline and 10 weeks	Supported by Plan Nacional I+D+I DEP2010-17574, Spain.
Romero-Areanas et al. 2007	Finland	High RT Circuit = 62.1 ± 6.3 yrs Traditional RT = 64.8 ± 4.5 yrs CON = 58 ± 5 yrs Male and female Healthy elderly	12 weeks 2 d per week	Supervised Weight machines High RT Circuit: 1-3 sets Traditional RT: 3 sets of 6-12 reps at 50-100% 6RM	Baseline and 12 weeks	Grant 07/UPR20/10 from the Consejo Superior de Deportes.
Sallinen et al. 2007	USA	RT = 57.9 ± 6.6 yrs CON = 58.2 ± 6.1 yrs Male Healthy elderly	21 weeks 1-3 d per week	Supervised Free weights, weight machines and body weight 3-6 sets of 5-10 reps at 40-80% 1RM	Baseline, 21 and 42 weeks	
Sawyer et al. 2014	Germany	Total cohort = 20.6 ± 2 yrs Male Physically active	8 weeks 3 d per week	Supervision not reported Free weights, weight machines and body weight 3 sets at 8RM	Baseline and 8 weeks	
Schiffer et al. 2011	Denmark	Total cohort = 22.6 ± 1.6 yrs Sex not reported Physically active	12 weeks 3 d per week	Supervised Weight machines 3 sets of 8-10 reps at 70-80% 1RM	Baseline and 12 weeks	Supported by the World Anti-Doping Agency.
Schmidt et al. 2014	USA	RT = 69.1 ± 3.1 yrs Football = 68 ± 4 yrs CON = 67.4 ± 2.7 yrs Male Healthy elderly	52 weeks 2 d per week	Supervised Free weights, weight machines and body weight 1-4 weeks: 4 sets of 16-20RM 5-8 weeks: 4 sets of 12RM 9-12 weeks: 4 sets of 10RM 13-52 weeks: 4 sets of 8RM	Baseline, 12 and 52 weeks	Supported by Nordea-fonden, FIFA Medical Assessment and Research Centre, Preben and Anna Simondsen fonden, and The Danish Ministry of Culture.
Schmitz et al. 2002	USA	RT =41 ± 6 yrs CON = 42 ± 6 yrs Female Healthy sedentary	15 weeks 2 d per week	Supervised Free weights and weight machines 3 sets of 8-10 reps	Baseline and 15 weeks	Supported by a Minnesota Obesity Centre Pilot and Feasibility Grant, NIH Grant DK50456 from the National

					Follow up at 39 weeks	Institute of Diabetes and Digestive and Kidney Diseases, University of Minnesota General Clinical Research Centre Grant M01- R00400, Tickle Family Fund for Breast Cancer Research, and Public Health Service Cancer Centre Support Grant P30 CA77398.
Schmitz et al. 2005	Canada	RT = 53.3 ± 8.7 yrs CON = 52.8 ± 7.6 yrs Female Breast cancer	26 weeks 2 d per week	Supervised for initial 13 weeks Free weights and weight machines 3 sets	Baseline, 24 and 52 weeks	S.G. Komen Foundation grant BCTR0100442 and NIH grants M01-RR00400 and T32 CA09607-15.
Segal et al. 2009	Iran	RT = 66.4 ± 7.6 yrs AT = 66.2 ± 6.8 yrs CON = 66.3 ± 7 yrs Male Prostate cancer	24 weeks 3 d per week	Supervised Free weights and weight machines 2 sets of 8-12 reps at 60-70% 1RM	Baseline and 24 weeks	Grant 013232 from the Canadian Prostate Cancer Research Fund.
Shamsoddini et al. 2015	South Africa	RT = 45.9 ± 7.3 yrs AT = 39.7 ± 6.3 yrs CON = 45.8 ± 7.3 yrs Males Non-alcoholic fatty liver disease	8 weeks 3 d per week	Supervised Free weights, weight machines and body weight 1-2 weeks: 2 sets of 10 reps at 50% 1RM 3-4 weeks: 2 sets of 10 reps at 60% 1RM 5-6 weeks: 3 sets of 10 reps at 60% 1RM 7-8 weeks: 3 sets of 10 reps at 70% 1RM	Baseline and 8 weeks	Supported by Exercise Physiology Research Centre and Research Centre for Gastroenterology and Liver Disease in Baqiyatallah University of Medical Sciences, Tehran, IR Iran.
Shaw & Shaw 2005	India	Age not reported Male Healthy sedentary	8 weeks 3 d per week	Supervision not reported Free weights, weight machines and body weight 3 sets of 15 reps at 60% 1RM	Baseline and 8 weeks	
Shenoy et al. 2009	Canada	RT = 49.6 ± 5.2 yrs AT = 52.2 ± 9.3 yrs CON = 58.4 ± 1.8 yrs Male and female Type 2 diabetes	16 weeks 2 d per week	Supervision not reported Free weights, weight machines and body weight 3 sets of 10 reps	Baseline and 16 weeks	Grant from the University Grants Commission, New Delhi, India.
Sigal et al. 2009	Finland	RT = 54.7 ± 7.5 yrs AT = 53.9 ± 6.6 yrs Combined = 53.5 ± 7.3 yrs CON = 54.8 ± 7.2 yrs Male and female Type 2 diabetes	22 weeks 3 d per week	Supervised Weight machines 2-3 sets of 7-9 reps	Baseline, 12 and 24 weeks	Grants from the Canadian Institutes of Health Research (grant MCT-44155), the Canadian Diabetes Association, a New Investigator Award from the Canadian Institutes of Health Research, Career Scientist Award from the Ontario Ministry of Health and Long Term Care, a Postgraduate Scholarship from the National Sciences and

						Engineering Research Council, a New Investigator Award from the Heart and Stroke Foundation, Doctoral Research Award from the Social Sciences and Humanities Research Council and an Ontario Graduate Scholarship.
Sillanpaa et al. 2012 Sillanpaa et al. 2009 Sillanpaa et al. 2009	USA	RT = 54.2 ± 8.1 yrs AT = 53.7 ± 8.2 yrs Combined = 53.9 ± 8 yrs CON = 54.5 ± 9.1 yrs Male and female Healthy elderly RT = 54.1 ± 6 yrs AT = 52.6 ± 7.9 yrs Combined = 56.3 ± 6.8 yrs CON = 53.8 ± 7.7 yrs Males RT = 50.8 ± 7.9 yrs AT = 51.7 ± 6.9 yrs Combined = 48.9 ± 6.8 yrs CON = 51.4 ± 7.8 yrs Female Healthy sedentary	21 weeks Endurance and strength - 2 d a week; Combined 4 d a week	Supervised Free weights, weight machines and body weight 3-4 sets 1-7 weeks: 15-20 reps at 40-60% 1RM 8-14 weeks: 10-12 reps at 60-80% 1RM 15-21 weeks: 6-8 reps at 70-80% 1RM	Baseline and 21 weeks	Supported, in part, by a grant from the Ministry of Education, Finland, the Central Finland Health Care District, Jyväskylä Finland, Juho Vainio Foundation, Finland, Sport Institute Foundation, Finland and Yrjö Jahnsson Foundation, Finland.
Simons & Andel 2006	Canada	RT = 84.6 ± 4.5 yrs Walking = 81.6 ± 3.3 yrs CON = 84 ± 3.3 yrs Male and female Healthy elderly	16 weeks 2 d per week	Supervised Weight machines 1 set of 10 reps at 75% 1RM	Baseline and 16 weeks	
Simpson et al. 1992	Korea	RT = 73 ± 4.8 yrs CON = 70 ± 5.7 yrs Male and female Chronic airflow limitation	8 weeks 3 d per week	Supervised Free weights and weight machines 3 sets of 10 reps at 50-85% 1RM	Baseline and 8 weeks	Grants from the Medical Research Council of Canada, the Heart and Stroke Foundation of Ontario, and the Ontario Thoracic Society.
Song & Sohng 2012	Brazil	RT = 52.1 ± 12.4 yrs CON = 54.6 ± 10.1 yrs Male and female Haemodialysis	12 weeks 3 d per week	Supervised Free weights and elastic resistance bands 3 sets of 10-15 reps	Baseline and 12 weeks	
Souza et al. 2013	UK	RT = 25.9 ± 6.4 yrs Interval Training = 24 ± 7.5 yrs CON = 22.5 ± 3.9 yrs	8 weeks 2 d a week	Supervision not reported Weight machines 1–2 weeks: 3 sets at 12RM 3–4 weeks: 4 sets at 8–10RM	Baseline and 8 weeks	Grants from Fundação de Amparo á Pesquisa do Estado de São Paulo - 2007/02738-6, 2010/51428-2, 2009/03143-1

		Male Physically active		5–6 weeks: 5 sets at 6–8RM 7–8 weeks: 3 sets at 10–12RM		and Conselho Nacional de Desenvolvimento Científi co e Tecnológico (CNPq) – 152658/2011-4, 470207/2008-6 and 303162/2008-2.
Stebbings et al. 2013	Belgium	RT = 19 ± 3 yrs CON = 23 ± 2.4 yrs Male and female Physically active	8 weeks (4 weeks of detraining) 3 d per week	Supervision of 2 sessions a week Weight machines and body weight 3 sets of 10 reps at 80% 1RM	Baseline, 8, 10 and 12 weeks	
Stegen et al. 2015	Norway	RT = 54.8 ± 7.6 yrs AT = 54 ± 6.6 yrs CON = 54.6 ± 7.1 yrs Combined = 53.6 ± 7.2 yrs Male and female Type 2 diabetes	24 weeks 3 d per week	Supervised Biweekly supervision after week 4 Weight machines 2-3 sets if 7-9 reps	Baseline and 24 weeks	Grants from the Research Foundation- Flanders (FWO G.0243.11 and G.0352), Canadian Institutes of Health Research (Grant MCT-44155), the Canadian Diabetes Association, a Health Senior Scholar Award from Alberta Innovates-Health Solutions and a Research Chair from the University of Ottawa.
Stensvold et al. 2010	Norway	RT = 50.9 ± 7.6 yrs AT = 49.9 ± 10.1 yrs Combined = 52.9 ± 10.4 yrs CON = 47.3 ± 10.2 yrs Male and female Metabolic syndrome	12 weeks 3 d per week	Supervised Week 1: 60% 1RM 2-13 weeks: 3 sets of 8-12 reps at 80% 1RM	Baseline and 12 weeks	Supported by the Liaison Committee between the Central Norway Regional Health Authority and the Norwegian University of Science and Technology.
Stensvold et al. 2012	Norway	RT = 50.9 ± 7.6 yrs AT = 49.9 ± 10.1 yrs CON = 47.3 ± 10.2 yrs Male and female Metabolic syndrome	13 weeks 4 d per week	Supervised Week 1: 60% 1RM 2-13 weeks: 3 sets of 8-12 reps at 80% 1RM	1 and 12 weeks	Grants from Raagholts Foundation.
Storen et al. 2008	Austria	RT = 28.6 ± 10.1 yrs CON = 29.7 ± 7 yrs Male and female Long distance runners	8 weeks 3 d per week	Supervised Free weights 4 sets at 4RM	Baseline and 8 weeks	
Strasser et al. 2009	Norway	RT = 74 ± 5 yrs AT = 76 ± 5 yrs CON = 74 ± 5 yrs Male and female Healthy elderly	24 weeks 3 d per week	Supervised Free weights, weight machines and body weight 3-6 sets (per week) of 10-15	Baseline and 24 weeks	
Sunde et al. 2010	Japan	RT = 29.9 ± 7.2 yrs CON = 35.8 ± 11.8 yrs Male and female Cyclists	8 weeks 3 d per week	Supervised Weight machines 4 sets at 4 RM	Baseline and 8 weeks	Supported by Telemark University College.

Tanimoto et al. 2009	Turkey	RT Low intensity = 19.0 ± 0.2 yrs RT High intensity = 19.5 ± 0.1 yrs CON = 19.8 ± 0.2 yrs Male Physically active	13 weeks 2 d per week	Supervision not reported RT Low intensity: 3 sets at 55-60% 1RM) RT High intensity: 3 sets at 85-90% 1RM	Baseline and 13 weeks	
Thabitha et al. 2012	India	Chronic obstructive pulmonary disease	3 d per week	Supervised Free weights and weight machines 1-3 sets of 10 reps	Baseline and endpoint (unknown)	
Tsutsumi et al. 1997	USA	RT high intensity/low volume = 67.8 ± 4.9 yrs RT low intensity/high volume = 68.9 ± 7.5 yrs CON = 69.8 ± 4.6 yrs Male Healthy elderly	12 weeks 3 d per week	Supervised RT high intensity/low volume: 8-12reps at 75-85% 1RM RT low intensity/high volume: 12-16 reps at 55-65% 1RM	Baseline and 12 weeks	
Van de Rest et al. 2014	Netherlands	Placebo: RT = 79.2 ± 6.3 yrs CON = 81.2 ± 7.4 yrs Protein: RT = 77.7 ± 8.8 yrs CON = 77.9 ± 8.1 yrs Male and female Healthy elderly	24 weeks 2 d per week	Supervised Weight machines 3-4 sets of 8-15 reps at 50-75% 1RM	Baseline and 24 weeks	Funded by Top Institute Food and Nutrition and co-financed by the Dutch Dairy Association (NZO) and the European Union's Seventh Framework Program under Grant Agreement No. 266486.
Vatani et al. 2011	Iran	Moderate intensity = 20.8 ± 1.5 yrs High intensity = 19.9 ± 0.7 yrs CON = 20.9 ± 1.1 yrs Male Healthy sedentary	6 weeks 3 d per week	Supervision not reported Weight machines MI- 45-55% 1RM in 3 sets with 10-12 reps per set HI - 80-90% 1RM in 3 sets with 4-6 reps per set	Baseline and 6 weeks	
Venojarvi et al. 2013 Venojarvi et al. 2013	Finland	RT = 54 ± 6.1 yrs Nordic walking = 55 ± 6.2 yrs CON = 54 ± 7.2 yrs RT = 54 ± 1.1 yrs Nordic walking = 55 ± 1 yrs CON = 54 ± 1 yrs Male Sedentary obese	13 weeks 4 d per week 12 weeks 3 d per week	Supervised Free weights and weight machines 5RM	Baseline and 12 weeks	Grants from the Research Council for Physical Education and Sports, the Finnish Ministry of Education, and Turku University of Applied Sciences R&D program. Grants from the Research Council for Physical Education and Sports, of the Finnish Ministry of Education, Turku University of Applied Sciences

						R&D program and the COST action CM1001.
Vincent et al. 2002 Vincent et al. 2003 Vincent et al. 2003	USA	LEX = 67.6 ± 6.3 yrs HEX = 66.6 ± 6.7 yrs CON = 71 ± 4.7 yrs LEX = 67.4 ± 7 yrs HEX = 66.5 ± 7 yrs CON = 71.1 ± 5 yrs LEX = 67.6 ± 6 yrs HEX = 66.6 ± 7 yrs CON = 71.1 ± 5 yrs Male and female Healthy elderly	24 weeks 3 d per week	Supervised Weight machines LEX – 1 set of 13 reps at 50% 1RM HEX – 1 set of 8 reps at 80% 1RM Supervision not reported	Baseline and 24 weeks	
Vincent et al. 2006	USA	Normal weight: RT = 68.1 ± 1.5 yrs CON = 70.9 ± 1.4 yrs Overweight/obese: RT = 66.5 ± 1.2 yrs CON = 71.2 ± 2.1 yrs Male and female Sedentary obese	24 weeks 3 d per week	Supervision not reported Weight machines 1 set of 8-13 reps at 50-80% 1RM	Baseline and 24 weeks	Supported, in part, by Grants T32-AT00052 and K30-AT-00,060 from the National Centre for Complementary and Alternative Medicine.
Vona et al. 2009	Switzerland	RT = 57 ± 8 yrs AT = 56 ± 6 yrs Combined = 55 ± 9 yrs CON = 58 ± 7 yrs Male and female Cardiac rehabilitation	4 weeks 4 d per week	Supervision not reported Free weights and elastic resistance bands 4 sets of 10-12 reps at 60% 1RM	Baseline and 4 weeks	
Wanderley et al. 2013	Portugal	RT = 67.3 ± 4.9 yrs AT = 69.9 ± 5.7 yrs CON = 67.8 ± 5.5 yrs Male and female Healthy elderly	32 weeks 3 d per week	Supervised Weight machines 2 sets of 12-15 reps at 50-60%1RM progressing to 80% 1RM at week 4	Baseline and 32 weeks	Supported by the Portuguese Foundation for Science and Technology (grant numbers, PTDC/DES/108780/2008 and SFRH/BD/33124/2007).
Weiser & Haber 2007	Austria	RT = 76.1 ± 2.9 yrs CON = not reported Male and female Healthy elderly	12 weeks 2 d per week	Supervision not reported Free weights, weight machines and body weight 1-4 weeks: 1 set of 10-15 reps 5-8 weeks: 3 sets of 10-15 reps 9-12 weeks: 4 sets of 10-15 reps	Baseline and 12 weeks	
Wiles et al. 2010	UK	18-34 years Male Physically active	8 weeks 3 d per week	Supervision not reported Isometric exercise 75% and 95% peak heart rate	Baseline, 4 and 8 weeks	

Yavari et al. 2012	Iran	RT = 51.5 ± 6.3 yrs AT = 48.2 ± 9.2 yrs Combined = 50.9 ± 9.8 yrs CON = 51.5 ± 8.5 yrs Sex not reported Type 2 diabetes	52 weeks 2-3 d per week	Supervised Weight machines 1-4 weeks: 1-2 sets of 8-10 reps at 60% 1RM 4-52 weeks: 3 sets of 8-10 reps at 75-80% 1RM	Baseline and 52 weeks	Grant from the Tabriz University of Medical Sciences and with a co-operation of Endocrinology Reasearch Centre of Emam Reza hospital (Tabriz University of Medical Sciences).
Yoshizawa et al. 2009	Japan	RT = 47 ± 2 yrs AET = 47 ± 2 yrs CON = 49 ± 3 yrs Female Healthy sedentary	12 weeks 2 d per week	Supervision not reported Weight machines 3 sets of 10 reps at 60% 1RM.	Baseline and 12 weeks	Supported by a Grant for Scientific Research from the Ministry of Education, Culture, Sports, Science and Technology of Japan (18300215, 18650186, 21970), and Health and Labour Sciences Research Grants from the Ministry of Health, Labour and Welfare, Japan.
Zambom-Ferraresi et al. 2015	Spain	RT = 68 ± 7 yrs RT + AT = 68 ± 7 yrs CON = 69 ± 5 yrs Male Chronic obstructive pulmonary disease	6 weeks 2 d per week	Supervision not reported Weight machines 3-4 sets of 6-12 reps at 50-70% 1RM	Baseline and 6 weeks	Support from the Spanish Ministry of Education and Science (Plan NacionalI + D + i 2004-2007 Strategic action: “Sport and physical education” Ref: DEP2007-73220), Health Sciences Department of Government of Navarre. F and a pre-doctoral fellowship from the Public University of Navarre.
Zavanela et al. 2012	Brazil	Age not reported Male Healthy sedentary	24 weeks 3-4 d per week	Supervised Free weights and weight machines 3 sets of 10–12 reps at 10–12RM	Baseline and 24 weeks	

Table 3. Populations used in the included studies.

	Population	Number	Percent
Healthy	Sedentary men and women	46	25.6
	Elderly men and women	30	16.7
	Physically active adults aged 18-35 years	20	11.1
	Postmenopausal women	5	2.8
Clinical			
Cardiac	Pre-hypertensive and newly diagnosed/never-treated hypertensive	3	1.7
	Coronary bypass graft	1	0.6
	Stable coronary heart failure	1	0.6
	Cardiac rehabilitation	1	0.6
Cancer	Breast cancer	3	1.7
	Disseminated germ cell cancer	1	0.6
	Prostate cancer	1	0.6
Non-cancer	Type 2 diabetes	18	10
	Sedentary obese/overweight	14	7.8
	Metabolic risk factors or syndrome	5	2.8
	Peripheral artery disease	4	2.2
	Chronic obstructive pulmonary disease	4	2.2
	Kidney transplant	3	1.7
	Musculoskeletal (e.g. osteoporosis, osteopenia or osteoarthritis	2	1.1
	Haemodialysis	2	1.1
	Non-alcoholic fatty liver disease	2	1.1
	Polycystic ovary syndrome	1	0.6
	HIV/AIDS	1	0.6
	Trapezius myalgia	1	0.6
	Total hip arthroplasty	1	0.6
	Chronic lumbar pain	1	0.6
	Cystic fibrosis	1	0.6
	Young men with depression/anxiety	1	0.6
	Impaired glucose tolerance	1	0.6
	Chronic airflow limitation	1	0.6

Table 4. Risk of bias assessment

Study	Random Sequence Generation	Allocation Concealment	Blinding of Participants and Personnel	Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Reporting
Ades et al. 1996	?	?	+	?	-	-
Afshar et al. 2010	?	?	+	?	-	-
Ahmadizad et al. 2007	?	?	+	?	-	+
Ahmadizad et al. 2014	?	?	+	?	-	-
Almenning et al. 2015	-	?	+	+	-	-
Anderson et al. 2004	?	?	+	?	-	-
Andersen et al. 2008	?	?	+	?	?	+
Andersen et al. 2014	?	?	+	?	-	?
Andersen et al. 2016	-	?	+	-	-	-
Arora et al. 2009	?	?	+	?	-	-
Asad et al. 2012	?	?	+	?	-	+
Augusto Libardi et al. 2012	?	?	+	?	-	-
Azarbayjani et al. 2014	?	?	+	?	+	-
Badrov et al. 2013	-	-	+	?	-	-
Baldi and Snowling 2003	?	?	+	?	-	-
de Barros et al. 2010	-	-	+	-	-	-
Beck et al. 2013	-	?	+	?	-	-
Bell et al. 2000	?	?	+	?	-	-
Beltran Valls et al. 2014	?	?	+	?	-	-
Boardley et al. 2007	+	+	+	?	+	-
Borges and Carvalho 2014	?	?	+	?	+	-
Brentano et al. 2008	?	?	+	?	-	-
Brito et al. 2013	?	-	+	?	-	-
Broeder et al. 1992	?	?	+	?	+	-
Brooks et al. 2007	?	?	+	-	-	-
Buchner et al. 1997	+	?	+	-	-	-
Camargo et al. 2008	?	?	+	-	-	-
Castaneda et al. 2002	?	?	+	?	-	-
Christensen et al. 2014	-	-	+	+	-	-
Colado et al. 2009	?	?	+	-	?	-
Conceição et al. 2013	?	?	+	?	-	-
Courneya et al. 2007	-	-	+	?	-	-
Croymans et al. 2013	-	?	+	-	-	-
Davidson et al. 2009	?	?	+	-	-	-
de Lima et al. 2012	?	?	+	?	-	-
De Souza et al. 2014	?	?	+	?	-	-
DeVallance et al. 2016	-	?	+	-	-	-
Deibert et al. 2011	?	?	+	?	-	-
Donges et al. 2010	+	?	+	?	-	-
Dunstan et al. 1998	?	?	+	?	?	-
Edge et al. 2006	?	?	+	?	-	-
Egana et al. 2010	?	?	+	?	-	-

Elliott et al. 2002	?	?	+	?	-	-
Fahlman et al. 2002	?	?	+	?	-	-
Fatouros et al. 2005	?	?	+	?	-	-
Fenkci et al. 2006	?	?	+	?	-	-
Figueroa et al. 2012	?	?	+	?	?	-
Franklin et al. 2015	?	?	+	?	-	-
Garcia-Lopez et al. 2007	?	?	+	?	-	-
Gater et al. 1992	?	?	+	?	?	-
Gelecek et al. 2012	-	?	+	-	-	-
Gettman et al. 1978	?	?	+	?	+	-
Gordon et al. 2006	?	?	+	?	-	-
Greenwood et al. 2015	-	?	+	-	+	-
Gregory et al. 2013	?	?	+	?	-	-
Hagberg et al. 1989	?	?	+	?	-	-
Hagerman et al. 2000	?	?	+	?	?	-
Hagstorm et al. 2016	-	?	+	-	-	-
Hallsworth et al. 2011	?	?	+	?	-	-
Hautala et al. 2006	?	?	+	?	+	-
Haykowsky 2000	?	?	+	?	-	-
Haykowsky 2005	?	?	+	?	?	-
Hedayati 2012	?	?	+	?	-	-
Heffernan 2013	?	?	+	?	?	-
Hendrickson 2012	?	?	+	?	-	-
Hiatt 1994	?	?	+	?	?	-
Holviala et al. 2012	?	?	+	?	-	-
Hoff 2007	?	?	+	?	?	-
Hoof et al. 1996	?	?	+	?	+	-
Horne et al. 1996	?	?	+	?	-	-
Hu et al. 2009	?	?	+	?	-	-
Huffman et al. 2014	-	?	+	?	-	-
Husby et al. 2009	-	-	+	?	-	-
Irving et al. 2015	?	?	+	?	-	-
Jay et al. 2011	-	?	+	-	-	-
Kaikkonen et al. 2000.	?	?	+	?	-	-
Kanegusuku et al. 2011	?	?	+	?	-	-
Karavirta et al. 2009	?	?	+	?	-	-
Karavirta et al. 2013	?	?	+	?	?	-
Karelis et al. 2016	-	-	+	?	-	-
Kawano et al. 2006	?	?	+	?	-	-
Kell and Asmundson 2009	?	?	+	?	-	-
Kemi et al. 2011	?	?	+	?	-	-
Kemmler et al. 2016	-	?	+	-	-	-
Khorvash et al. 2012	?	?	+	?	+	?
Kim et al. 2011	?	?	+	?	-	-
Ku et al. 2010	?	?	+	?	-	-
Kwon et al. 2010	?	?	+	?	+	-
Kwon et al. 2011	?	?	+	?	-	-
Larose et al. 2010	?	?	+	?	-	-
LeMura et al. 2000	?	?	+	?	-	-
Levinger et al. 2007	?	?	+	?	-	-
Libardi et al. 2011	?	?	+	?	-	-
Lo et al. 2011	?	?	+	?	?	-
Lovell et al. 2009	-	?	+	-	-	-

Madden et al. 2006	?	?	+	?	?	-
Mahdirejei et al. 2014	?	?	+	?	-	-
Maiorana et al. 1997	?	?	+	?	-	-
Maiorana et al. 2011	?	?	+	?	-	-
Malin et al. 2013	+	?	+	?	-	-
Manning et al. 1991	?	?	+	?	-	-
Marcinik et al. 1991	?	?	+	?	-	-
Marcus et al. 2009	?	?	+	?	-	-
Martins et al. 2010	?	?	+	?	-	-
McDermott et al. 2009	-	?	+	-	-	-
McGuigan et al. 2001	?	?	+	?	?	-
Mikesky et al. 1994	+	?	+	?	-	-
Miller et al. 2008	?	?	+	?	-	-
Miura et al. 2008	?	?	+	?	-	-
Miyachi et al. 2004	?	?	+	?	-	-
Mosti et al. 2013	?	?	+	?	-	-
Mosti et al. 2014	-	?	+	?	-	-
Mota et al. 2013	+	+	+	?	-	-
Nikseresht et al. 2014	?	?	+	?	-	-
Nybo et al. 2010	+	+	+	?	-	-
O'Connor et al. 2017	-	-	+	-	?	-
Okamoto et al. 2006	?	?	+	-	-	-
Okamoto et al. 2009a	?	?	+	-	-	-
Okamoto et al. 2009b	?	?	+	?	-	-
Okamoto et al. 2011	?	?	+	-	-	-
Okamoto et al. 2013	?	?	+	?	-	-
Oldervoll et al. 2001	+	?	+	?	?	-
Oliveira et al. 2013	?	?	+	?	-	-
Olson et al. 2006	?	?	+	?	-	-
Panton et al. 1990	?	?	+	?	-	-
Parr et al. 2009	-	?	+	?	-	-
Perez-Gomez et al. 2013	?	?	+	?	-	-
Plotnikoff et al. 2010	-	-	+	?	-	-
Poehlman et al. 2000	?	?	+	?	?	-
Poehlman et al. 2002	?	?	+	?	?	-
Pollock et al. 1991	?	?	+	?	-	-
Prabhakaran et al. 1999	?	?	+	?	-	-
Rana et al. 2008	?	?	+	?	?	-
Roberts et al. 2013	?	?	+	?	+	-
Rodriguez-Miguelez et al. 2014	?	?	+	?	?	-
Romero-Areanas et al. 2013	?	?	+	?	?	-
Sallinen et al. 2007	?	?	+	?	-	-
Sawyer et al. 2014	?	?	+	?	?	-
Schiffer et al. 2011	?	?	+	?	?	-
Schmidt et al. 2014	?	?	+	-	-	-
Schmitz et al. 2002	?	?	+	-	-	?
Schmitz et al. 2005	-	-	+	-	-	-
Segal et al. 2009	-	-	+	?	-	-
Shamsoddini et al. 2015	?	?	+	?	?	-
Shaw and Shaw 2005	-	?	+	?	?	-
Shenoy et al. 2009	?	?	+	?	-	-
Sigal et al. 2009	-	-	+	-	-	-
Sillanpaa et al. 2012	-	?	+	?	?	-

Simons and Andel 2006	?	?	+	-	-	-
Simpson et al. 1992	+	?	+	?	+	-
Song and Sohng 2012	?	?	+	?	-	-
Souza et al. 2013	?	?	+	?	?	-
Stebbings et al. 2013	?	?	+	-	?	-
Stegen et al. 2015	?	?	+	?	-	-
Stensvold et al. 2010	-	?	+	?	-	-
Stensvold et al. 2012	-	?	+	?	-	-
Strasser et al. 2009	-	?	+	?	?	-
Tanimoto et al. 2009	?	?	+	?	-	-
Thabitha et al. 2012	?	?	+	?	?	-
Tsutsumi et al. 1997	?	?	+	?	-	-
Van de Rest et al. 2014	-	-	+	?	-	?
Vatani et al. 2011	?	?	+	?	?	-
Venojarvi et al. 2013	?	?	+	?	?	-
Vincent et al. 2002	?	?	+	?	?	-
Vincent et al. 2006	?	?	+	?	?	-
Vona et al. 2009	?	?	+	?	-	-
Wanderley et al. 2013	-	?	+	?	+	-
Weiser and Haber 2007	-	?	+	?	?	-
Wiles et al. 2010	-	?	+	?	?	-
Yavari et al. 2012	?	?	+	?	+	-
Yoshizawa et al. 2009	?	?	+	?	-	-
Zambom-Ferraresi et al. 2015	-	?	+	-	-	-
Zavanela et al. 2012	?	?	+	?	?	-

Table 5. The short- (ST), medium- (MT) and long-term (LT) effects of RET on all outcomes reported in healthy young adults aged 18-40 years.

Blood marker		Number of studies	Number of participants		Mean difference [95% CI]	P values	Heterogeneity
			RT	CON			
SBP (mmHg)	MT	11	150	122	-0.56 [-1.57, 0.44] †	0.27	χ^2 = 49.4, I^2 = 80%, P < 0.00001
DBP (mmHg)	MT	11	150	124	-0.81 [-1.59, -0.04] †	0.04*	χ^2 = 41.91, I^2 = 76%, P < 0.00001
MAP (mmHg)	MT	4	44	41	3.48 [2.09, 4.87] #	< 0.00001*	χ^2 = 4.19, I^2 = 28%, P = 0.24
RHR (bpm)	MT	12	157	130	0.12 [-0.79, 1.03]	0.79	χ^2 = 163.07, I^2 = 93%, P < 0.00001
$\dot{V}O_2$max (ml/kg/min)	ST	3	31	24	2.53 [-0.01, 5.07] †	0.05*	χ^2 = 5.06, I^2 = 61%, P = 0.08
	MT	11	161	126	0.91 [0.29, 1.53] †	0.004*	χ^2 = 28.23, I^2 = 65%, P = 0.002
	LT	2	33	39	-1.35 [-4.03, 1.33] #	0.32	χ^2 = 0.01, I^2 = 0%, P = 0.91
Total Cholesterol (mg/dL)	MT	6	63	67	6.23 [2.97, 9.49] #	0.0002*	χ^2 = 83.22, I^2 = 94%, P < 0.00001
HDL-chol (mg/dL)	MT	6	78	76	1.85 [0.74, 2.97] †	0.001*	χ^2 = 42.3, I^2 = 88%, P < 0.00001
LDL-chol (mg/dL)	MT	6	78	76	-0.30 [-2.49, 1.88] †	0.78	χ^2 = 70.26, I^2 = 93%, P < 0.00001
Triglycerides (mg/dL)	MT	5	70	65	1.74 [0.04, 3.44] #	0.04*	χ^2 = 9.64, I^2 = 59%, P = 0.05
Fasted glucose (mg/dL)	MT	4	40	43	3.12 [2.02, 4.22] #	< 0.00001*	χ^2 = 21.93, I^2 = 86%, P < 0.0001

* Indicates statistical significance. † Indicates favouring resistance exercise training. # Indicates favouring control. ST - short term, MT – medium term, LT – long term, V̇O2max – aerobic capacity, HDL-chol – high density lipoprotein cholesterol, LDL-chol – low density lipoprotein cholesterol.

Table 6. The short- (ST), medium- (MT) and long-term (LT) effects of RET on all outcomes reported in healthy older adults ≥ 41 years of age.

Blood marker		Number of studies	Number of participants		Mean difference [95% CI]	P values	Heterogeneity
			RT	CON			
SBP (mmHg)	MT	12	180	166	-4.36 [-5.73, -2.99] †	< 0.00001*	χ^2 = 41.02, I^2 = 73%, P < 0.00001
	LT	3	72	57	-1.89 [-7.66, 3.88] †	0.52	χ^2 = 0.31, I^2 = 0%, P = 0.86
DBP (mmHg)	MT	12	180	166	-1.51 [-2.47, -0.54] †	0.002*	χ^2 = 75.02, I^2 = 85%, P < 0.00001
	LT	3	72	57	-5.95 [-9.30, -2.61] †	0.0005*	χ^2 = 15.57, I^2 = 87%, P = 0.0004
MAP (mmHg)	MT	3	32	27	-3.91 [-5.37, -2.45] †	< 0.00001*	χ^2 = 2.0, I^2 = 0%, P = 0.37
RHR (bpm)	MT	13	214	186	1.80 [0.84, 2.77] #	0.0003*	χ^2 = 34.42, I^2 = 65%, P = 0.0006
	LT	3	48	34	0.52 [-1.25, 2.30] #	0.56	χ^2 = 3.6, I^2 = 44%, P = 0.17
$\dot{V}O_2max$ (ml/kg/min)	MT	13	220	186	-0.31 [-0.90, 0.27]	0.3	χ^2 = 29.33, I^2 = 59%, P = 0.004
	LT	7	125	91	1.30 [0.47, 2.13] †	0.002*	χ^2 = 2.28, I^2 = 0%, P = 0.002
Total Cholesterol (mg/dL)	MT	8	109	106	-8.20 [-14.52, -1.89] †	0.01*	χ^2 = 10.4, I^2 = 33%, P = 0.17
	LT	3	45	28	-19.99 [-36.18, -3.80] †	0.02*	χ^2 = 2.32, I^2 = 14%, P = 0.31
HDL-chol (mg/dL)	MT	11	150	140	11.55 [10.16, 12.94] †	< 0.00001*	χ^2 = 368.51, I^2 = 97%, P < 0.00001
	LT	3	45	28	5.01 [-0.10, 10.13] †	0.05	χ^2 = 8.16, I^2 = 75%, P = 0.02
LDL-chol (mg/dL)	MT	8	109	108	-1.60 [-6.58, 3.37] †	0.53	χ^2 = 43.85, I^2 = 84%, P < 0.00001
	LT	2	30	18	-5.63 [-15.79, 4.53] †	0.28	χ^2 = 1.14, I^2 = 12%, P = 0.29
Triglycerides (mg/dL)	MT	10	151	146	-13.27 [-15.92, -10.61] †	< 0.00001*	χ^2 = 112.64, I^2 = 92%, P < 0.00001
	LT	2	30	18	6.02 [-8.62, 20.66] #	0.42	χ^2 = 0.27, I^2 = 0%, P = 0.61
Fasted insulin (µU/ml)	MT	3	73	73	-1.09 [-1.28, -0.89] †	< 0.00001*	χ^2 = 2.1, I^2 = 5%, P = 0.35
	LT	2	47	48	0.27 [-0.03, 0.57]	0.08	χ^2 = 0.43, I^2 = 0%, P = 0.51
HOMA-IR	LT	2	23	18	-0.44 [-1.07, 0.19] †	0.17	χ^2 = 0.1, I^2 = 0%, P = 0.75
Fasted glucose (mg/dL)	MT	7	134	130	-4.82 [-6.26, -3.38] †	< 0.00001*	χ^2 = 123.38, I^2 = 95%, P < 0.00001
	LT	3	56	47	3.06 [2.30, 3.82] #	< 0.00001*	χ^2 = 5.45, I^2 = 63%, P = 0.07
CRP (mg/L)	MT	4	74	69	-0.26 [-0.32, -0.20] †	< 0.00001*	χ^2 = 4.71, I^2 = 36%, P = 0.19

* Indicates statistical significance. † Indicates favouring resistance exercise training. # Indicates favouring control. ST – short term, MT – medium term, LT – long term, HDL-chol – high density lipoprotein cholesterol, LDL-chol – low density lipoprotein cholesterol, HOMA-IR – insulin resistance, CRP – C-reactive protein.

Table 7. The short- (ST), medium- (MT) and long-term (LT) effects of RET on all outcomes reported in older adults ≥ 41 years old with cardiometabolic risk factors.

Blood marker		Number of studies	Number of participants		Mean difference [95% CI]	P values	Heterogeneity
			RT	CON			
SBP (mmHg)	ST	2	37	37	-5.19 [-7.55, -2.83] †	< 0.0001*	χ^2 = 4.4, I^2 = 77%, P = 0.04
	MT	17	304	312	-8.80 [-9.90, -7.69] †	< 0.00001*	χ^2 = 95.83, I^2 = 83%, P < 0.00001
	LT	4	101	106	-3.42 [-8.03, 1.19] †	0.15	χ^2 = 4.69, I^2 = 36%, P = 0.2
DBP (mmHg)	ST	2	37	37	-2.47 [-4.59, -0.35] †	0.02*	χ^2 = 5.45, I^2 = 82%, P = 0.02
	MT	15	219	230	-2.55 [-3.09, -2.01] †	< 0.00001*	χ^2 = 103.88, I^2 = 87%, P < 0.00001
	LT	3	90	97	-1.99 [-5.15, 1.18] †	0.22	χ^2 = 2.27, I^2 = 12%, P = 0.32
MAP (mmHg)	MT	2	22	24	-5.92 [-7.72, -4.13] †	< 0.00001*	χ^2 = 0.17, I^2 = 0%, P = 0.68
RHR (bpm)	MT	6	81	89	-0.44 [-1.45, 0.58] †	0.4	χ^2 = 55.3, I^2 = 91%, P < 0.00001
	LT	2	26	34	-3.06 [-8.19, 2.06] †	0.24	χ^2 = 1.55, I^2 = 36%, P = 0.21
$\dot{V}O_2$max (ml/kg/min)	ST	3	74	68	3.02 [2.45, 3.59] †	< 0.00001*	χ^2 = 1.74, I^2 = 0%, P = 0.42
	MT	11	178	186	2.38 [1.78, 2.98] †	< 0.00001*	χ^2 = 47.0, I^2 = 79%, P < 0.00001
Total Cholesterol (mg/dL)	MT	10	125	127	6.65 [3.70, 9.60] #	< 0.00001*	χ^2 = 62.61, I^2 = 86%, P < 0.00001
	LT	2	26	34	-7.16 [-25.94, 11.61] †	0.45	χ^2 = 0.05, I^2 = 0%, P = 0.82
HDL-chol (mg/dL)	MT	14	243	243	1.86 [0.85, 2.87] †	0.0003*	χ^2 = 26.2, I^2 = 50%, P = 0.02
	LT	3	90	97	2.03 [-1.81, 5.87] †	0.3	χ^2 = 0.0, I^2 = 0%, P = 1.0
LDL-chol (mg/dL)	MT	9	186	182	-13.42 [-15.94, -10.91] †	< 0.00001*	χ^2 = 98.19, I^2 = 92%, P < 0.00001
	LT	3	90	97	-0.22 [-13.57, 13.13] †	0.97	χ^2 = 0.86, I^2 = 0%, P = 0.65
Triglycerides (mg/dL)	MT	14	225	220	-5.75 [-9.62, -1.87] †	0.004*	χ^2 = 28.15, I^2 = 54%, P = 0.009
	LT	3	90	97	-17.69 [-36.83, 1.45] †	0.07	χ^2 = 3.89, I^2 = 49%, P = 0.14
Fasted insulin (µU/ml)	MT	11	139	128	-1.44 [-2.43, -0.45] †	0.004*	χ^2 = 38.07, I^2 = 74%, P < 0.0001
HOMA-IR	MT	4	43	40	-2.84 [-3.19, -2.50] †	< 0.00001*	χ^2 = 3.31, I^2 = 9%, P = 0.35
Fasted glucose (mg/dL)	MT	14	187	180	-2.19 [-4.09, -0.29] †	0.02*	χ^2 = 59.26, I^2 = 78%, P < 0.00001
	LT	2	26	34	-25.57 [-40.04, -11.10] †	0.0005*	χ^2 = 1.02, I^2 = 2%, P = 0.0005
CRP (mg/L)	MT	4	58	58	-2.47 [-3.97, -0.98] †	0.001*	χ^2 = 9.93, I^2 = 70%, P = 0.02

* Indicates statistical significance. † Indicates favouring resistance exercise training. # Indicates favouring control. ST – short term, MT – medium term, LT – long term, HDL-chol – high density lipoprotein cholesterol, LDL-chol – low density lipoprotein cholesterol, HOMA-IR – insulin resistance, CRP – C-reactive protein.

Table 9. GRADE summary of findings.

Outcome		Anticipated absolute effects (95% CI)		Number of participants (RCTs)	Certainty
		Risk with no exercise control or usual care	Risk with resistance exercise training		
Cardiovascular morbidity and mortality		Could not be calculated due to lack of reporting.			
SBP (mmHg)	ST	The mean SBP – ST was **115.45** mmHg	MD **3.17 mmHg lower** (6.95 lower to 0.6 higher)	116 (4 RCTs)	⊕◯◯◯ VERY LOW [a,b,c]
	MT	The mean SBP – MT was **122.8** mmHg	MD **4.02 mmHg lower** (5.92 lower to 2.11 lower)	1456 (46 RCTs)	⊕◯◯◯ VERY LOW [a,c,d]
	LT	The mean SBP – LT was **131.6** mmHg	MD **4.88 mmHg lower** (10.55 lower to 0.78 higher)	346 (7 RCTs)	⊕⊕◯◯ LOW [a,c]
MAP (mmHg)	ST	The mean MAP- ST was **86.5** mmHg	MD **3.31 mmHg lower** (6.86 lower to 0.78 higher)	67 (3 RCTs)	⊕◯◯◯ VERY LOW [a,b,c,d]
	MT	The mean MAP- MT was **79.6** mmHg	MD **1.57 mmHg lower** (4.6 lower to 1.46 higher)	238 (10 RCTs)	⊕◯◯◯ VERY LOW [a,b,c,d]
DBP (mmHg)	ST	The mean DBP – ST was **65.2** mmHg	MD **1.44 mmHg lower** (4.73 lower to 1.86 higher)	52 (3 RCTs)	⊕◯◯◯ VERY LOW [a,b,c]
	MT	The mean DBP – MT was **74.3** mmHg	MD **1.73 mmHg lower** (2.88 lower to 0.57 lower)	1418 (45 RCTs)	⊕⊕◯◯ LOW [a,c]
	LT	The mean DBP - LT was **76.0** mmHg	MD **4.93 mmHg lower** (8.58 lower to 1.28 lower)	346 (7 RCTs)	⊕◯◯◯ VERY LOW [a,b,c,d]
RHR (bpm)	ST	The mean RHR– ST was **72** bpm	MD **2.66 bpm lower** (7.55 lower to 2.23 higher)	30 (2 RCTs)	⊕◯◯◯ VERY LOW [a,b,c,d]
	MT	The mean RHR– MT was **67.8** bpm	MD **0.35 bpm higher** (1.44 lower to 2.13 higher)	977 (35 RCTs)	⊕◯◯◯ VERY LOW [a,c,d]
	LT	The mean RHR – LT was **57.4** bpm	MD **0.48 bpm lower** (3.12 lower to 2.17 higher)	142 (5 RCTs)	⊕◯◯◯ VERY LOW [a,b,c,e]
Flow Mediated Dilatation (%)		The mean Flow Mediated Dilatation was **7.8** %	MD **1.69 % higher** (0.97 higher to 2.41 higher)	138 (6 RCTs)	⊕⊕◯◯ LOW [a,c]
Total Cholesterol (mg/dL)	ST	The mean Total Cholesterol – ST was **179.3** mg/dL	MD 5.55 **mg/dL lower** (9.62 lower to 5.47 higher)	146 (3 RCTs)	⊕◯◯◯ VERY LOW [a,c,e]
	MT	The mean Total Cholesterol – MT was **180.9** mg/dL	MD **0.57 mg/dL higher** (5.63 lower to 6.77 higher)	882 (32 RCTs)	⊕◯◯◯ VERY LOW [a,c,d]
	LT	The mean Total Cholesterol – LT was **198.6** mg/dL	MD **8.71 mg/dL lower** (30.83 lower to 13.4 higher)	212 (8 RCTs)	⊕◯◯◯ VERY LOW [a,b,c,d,e]
HDL-chol (mg/dL)	ST	The mean HDL-Chol – ST was **53.8** mg/dL	MD **0.82 mg/dL higher** (5.4 lower to 7.03 higher)	146 (3 RCTs)	⊕◯◯◯ VERY LOW [a,b,c,e]
	MT	The mean HDL-Chol – MT was **53.3** mg/dL	MD **2.35 mg/dL higher** (0.66 lower to 5.35 higher)	1114 (38 RCTs)	⊕◯◯◯ VERY LOW [a,c,d]
	LT	The mean HDL-Chol – LT was **53.5** mg/dL	MD **2.79 mg/dL higher** (0.69 lower to 6.82 higher)	339 (9 RCTs)	⊕⊕◯◯ LOW [a,c]
LDL-chol (mg/dL)	ST	The mean LDL-Chol – ST was **105.6** mg/dL	MD **5.1 mg/dL lower** (11.09 lower to 0.9 higher)	146 (3 RCTs)	⊕◯◯◯ VERY LOW [a,b,c,e]
	MT	The mean LDL-Chol - MT was **110.1** mg/dL	MD **2.86 mg/dL lower** (8.77 lower to 3.05 higher)	1000 (31 RCTs)	⊕◯◯◯ VERY LOW [a,c,d]
	LT	The mean LDL-Chol - LT was **118.3** mg/dL	MD **3.69 mg/dL lower** (10.99 lower to 3.6 higher)	265 (6 RCTs)	⊕◯◯◯ VERY LOW [a,b,c]
Triglycerides (mg/dL)	ST	The mean Triglycerides - ST was **115.2** mg/dL	MD **3.63 mg/dL lower** (17.45 lower to 10.2 higher)	146 (3 RCTs)	⊕◯◯◯ VERY LOW [a,b,c,e]
	MT	The mean Triglycerides - MT was **91.8** mg/dL	MD **3.99 mg/dL lower** (8.78 lower to 0.8 higher)	1165 (37 RCTs)	⊕◯◯◯ VERY LOW [a,c,d]
	LT	The mean Triglycerides - LT was **102.7** mg/dL	MD **2.82 mg/dL lower** (14.98 lower to 9.33 higher)	265 (6 RCTs)	⊕◯◯◯ VERY LOW [a,b,c]

Fasted insulin (μU/ml)	MT	The mean Insulin (fasted) – MT was **16.2** μU/ml	MD **1.11 μU/ml lower** (1.74 lower to 0.49 lower)	590 (20 RCTs)	⊕◯◯◯ VERY LOW [a,c,d]
	LT	The mean Insulin (fasted) - LT was **13.8** μU/ml	MD **0.4 μU/ml lower** (1.62 lower to 0.81 higher)	179 (4 RCTs)	⊕◯◯◯ VERY LOW [a,b,c,d]
HOMA-IR	MT	The mean Insulin Resistance (HOMA) – MT was **6.1**	MD **1.22 lower** (2.29 lower to 0.15 lower)	184 (9 RCTs)	⊕◯◯◯ VERY LOW [a,b,c,d]
	LT	The mean Insulin Resistance (HOMA) – LT was **3.8**	MD **0.18 lower** (0.64 lower to 0.27 higher)	71 (3 RCTs)	⊕◯◯◯ VERY LOW [a,b,c]
Fasted glucose (mg/dL)	ST	The mean Glucose – ST was **87.3** mg/dL	MD **3.39 mg/dL lower** (6.9 lower to 0.11 higher)	122 (2 RCTs)	⊕◯◯◯ VERY LOW [a,b,c]
	MT	The mean Glucose – MT was **100.7** mg/dL	MD **2.39 mg/dL lower** (4.47 lower to 0.31 lower)	984 (34 RCTs)	⊕◯◯◯ VERY LOW [a,c,d]
	LT	The mean Glucose – LT was **92.3** mg/dL	MD **0.7 mg/dL lower** (2.8 lower to 2.67 higher)	271 (7 RCTs)	⊕◯◯◯ VERY LOW [a,b,c,d]
CRP (mg/L)	ST	The mean hs-CRP – ST was **2.4** mg/L	MD **0.13 mg/L lower** (0.25 lower to 0.01 lower)	82 (2 RCTs)	⊕◯◯◯ VERY LOW [a,b,c,e]
	MT	The mean hs-CRP – MT was **3.2** mg/L	MD **0.11 mg/L lower** (0.6 lower to 0.38 higher)	394 (12 RCTs)	⊕◯◯◯ VERY LOW [a,c,d]
$\dot{V}O_2max$ (ml/kg/min)	ST	The mean $\dot{V}O_2max$ – ST was **28.6** ml/kg/min	MD **2.07 ml/kg/min higher** (0.75 higher to 3.39 higher)	308 (9 RCTs)	⊕◯◯◯ VERY LOW [a,b,c]
	MT	The mean $\dot{V}O_2max$ - MT was **28.9** ml/kg/min	MD **1.07 ml/kg/min higher** (0.38 higher to 1.76 higher)	1454 (48 RCTs)	⊕◯◯◯ VERY LOW [a,c,d,e]
	LT	The mean $\dot{V}O_2max$ - LT was **23** ml/kg/min	MD **1.22 ml/kg/min higher** (0.44 higher to 2.0 higher)	399 (11 RCTs)	⊕◯◯◯ VERY LOW [a,c,e]

CI - Confidence interval; RCTs – randomised control trials; MD – mean difference; ST – short term; MT – medium term; LT – long term; SBP – systolic blood pressure; DBP - diastolic blood pressure; MAP – mean arterial pressure; RHR – resting heart rate; HDL-chol – high density lipoprotein cholesterol; LDL-chol – low density lipoprotein cholesterol; HOMA-IR – insulin resistance; CRP – C-reactive protein; $\dot{V}O_2max$ – aerobic capacity.
a – Downgraded due to being a surrogate outcome.
b – Downgraded due to potential for a recommendation or clinical course of action differing if the upper versus the lower boundary of the CI represented the truth and/or a sample size <400.
c – Publication bias suspected after inspection of funnel plots.
d – Inconsistent due to high heterogeneity, non-overlap of CI and/or markedly dissimilar point estimates.
e – Risk of bias was judged to be high.

Table 8. Sensitivity analysis of the short- (ST), medium- (MT) and long-term (LT) effects of RET on cardiometabolic outcomes.

Outcome		Number of studies	Number of participants		Mean difference [95% CI]	P values	Heterogeneity
			RT	CON			
SBP (mmHg)	ST	2	22	20	-2.49 [-7.14, 2.16]	0.29	$\chi^2 = 0.32$, $I^2 = 0\%$, $P = 0.27$ *
	MT	39	607	572	-4.14 [-6.36, -1.92]	0.0003	$\chi^2 = 301.18$, $I^2 = 87\%$, $P < 0.00001$
	LT	5	151	135	-3.88 [-11.18, 3.42]	0.3	$\chi^2 = 17.62$, $I^2 = 77\%$, $P = 0.001$
DBP (mmHg)	ST	2	22	20	0.41 [-2.36, 3.18]	0.77	$\chi^2 = 0.04$, $I^2 = 0\%$, $P = 0.84$ *
	MT	38	597	564	-1.86 [-3.19, -0.52]	0.006	$\chi^2 = 231.14$, $I^2 = 84\%$, $P < 0.00001$
	LT	5	138	138	-3.99 [-6.34, -1.64]	0.0009	$\chi^2 = 5.29$, $I^2 = 24\%$, $P = 0.26$ *
MAP (mmHg)	ST	2	22	20	-1.38 [-4.30, 1.54]	0.35	$\chi^2 = 0.04$, $I^2 = 0\%$, $P = 0.85$ *
	MT	9	128	125	-1.22 [-4.34, 1.90]	0.44	$\chi^2 = 95.95$, $I^2 = 92\%$, $P < 0.00001$
Resting Heart Rate (bpm) † §	MT	30	450	414	0.91 [-0.99, 2.81]	0.35	$\chi^2 = 236.88$, $I^2 = 88\%$, $P < 0.00001$
FMD (%)		6	68	70	1.69 [0.97, 2.41]	< 0.0001	$\chi^2 = 0.72$, $I^2 = 0\%$, $P = 0.98$
$\dot{V}O_2$max (ml/kg/min)	ST	7	159	115	1.52 [-0.13, 3.17]	0.07	$\chi^2 = 10.10$, $I^2 = 41\%$, $P = 0.12$
	MT	36	631	568	1.25 [0.45, 2.05]	0.002	$\chi^2 = 119.6$, $I^2 = 71\%$, $P < 0.00001$
	LT	6	128	101	1.82 [0.60, 3.04]	0.003	$\chi^2 = 0.6$, $I^2 = 0\%$, $P = 0.99$ *
Total Cholesterol (mg/dL)	ST	2	70	56	-2.07 [-9.62, 5.47]	0.59	$\chi^2 = 0.01$, $I^2 = 0\%$, $P = 0.92$ *
	MT	26	336	325	-3.78 [-9.12, 1.57]	0.17	$\chi^2 = 66.33$, $I^2 = 62\%$, $P < 0.0001$ *
	LT	4	56	52	-6.31 [-18.30, 5.68]	0.3	$\chi^2 = 1.34$, $I^2 = 0\%$, $P = 0.72$ *
HDL-chol (mg/dL)	ST	2	70	56	-2.17 [-6.26, 1.91]	0.3	$\chi^2 = 0.03$, $I^2 = 0\%$, $P = 0.86$ *
	MT	33	495	475	2.64 [-1.03, 6.31]	0.16	$\chi^2 = 563.25$, $I^2 = 94\%$, $P < 0.00001$ *
	LT	5	120	115	0.80 [-3.07, 4.66]	0.12	$\chi^2 = 3.12$, $I^2 = 0\%$, $P = 0.54$ *
LDL-chol (mg/dL)	ST	2	70	56	-4.78 [-10.98, 1.42]	0.13	$\chi^2 = 0.17$, $I^2 = 0\%$, $P = 0.68$
	MT	25	397	382	-7.17 [-13.24, -1.09]	0.02	$\chi^2 = 147.44$, $I^2 = 84\%$, $P < 0.00001$ *
	LT	4	109	96	-3.97 [-11.86, 3.92]	0.32	$\chi^2 = 1.57$, $I^2 = 0\%$, $P = 0.67$
Triglycerides (mg/dL)	ST	2	70	56	-4.36 [-19.10, 10.37]	0.56	$\chi^2 = 0.06$, $I^2 = 0\%$, $P = 0.81$
	MT	32	492	471	-5.06 [-10.64, 0.53]	0.08	$\chi^2 = 233.71$, $I^2 = 87\%$, $P < 0.00001$
	LT	4	109	96	0.19 [-7.78, 8.16]	0.96	$\chi^2 = 1.93$, $I^2 = 0\%$, $P = 0.59$ *
Fasted insulin (µU/ml)	MT	16	246	226	-1.52 [-2.66, -0.39]	0.009	$\chi^2 = 47.11$, $I^2 = 66\%$, $P < 0.0001$ *
	LT	4	89	90	-0.60 [-1.93, 0.72]	0.37	$\chi^2 = 45.43$, $I^2 = 93\%$, $P < 0.00001$
HOMA-IR	MT	9	86	78	-1.40 [-2.58, -0.22]	0.02	$\chi^2 = 74.57$, $I^2 = 91\%$, $P < 0.00001$ *
	LT	3	38	33	-0.18 [-0.64, 0.27]	0.6	$\chi^2 = 1.45$, $I^2 = 0\%$, $P = 0.48$
Fasted glucose (mg/dL)	ST	2	64	58	-3.39 [-6.90, 0.11]	0.06	$\chi^2 = 1.66$, $I^2 = 40\%$, $P = 0.2$
	MT	27	410	397	-2.91 [-5.34, -0.47]	0.02	$\chi^2 = 310.64$, $I^2 = 91\%$, $P < 0.00001$
	LT	5	109	102	0.96 [-1.45, 3.38]	0.43	$\chi^2 = 31.42$, $I^2 = 87\%$, $P < 0.00001$
CRP (mg/L) †	MT	9	135	135	0.04 [-0.30, 0.38]	0.8	$\chi^2 = 7.59$, $I^2 = 0\%$, $P = 0.47$ *

† ST could not be calculated due to a lack of studies.
§ LT could not be calculated due to a lack of studies.
* Reduction in heterogeneity

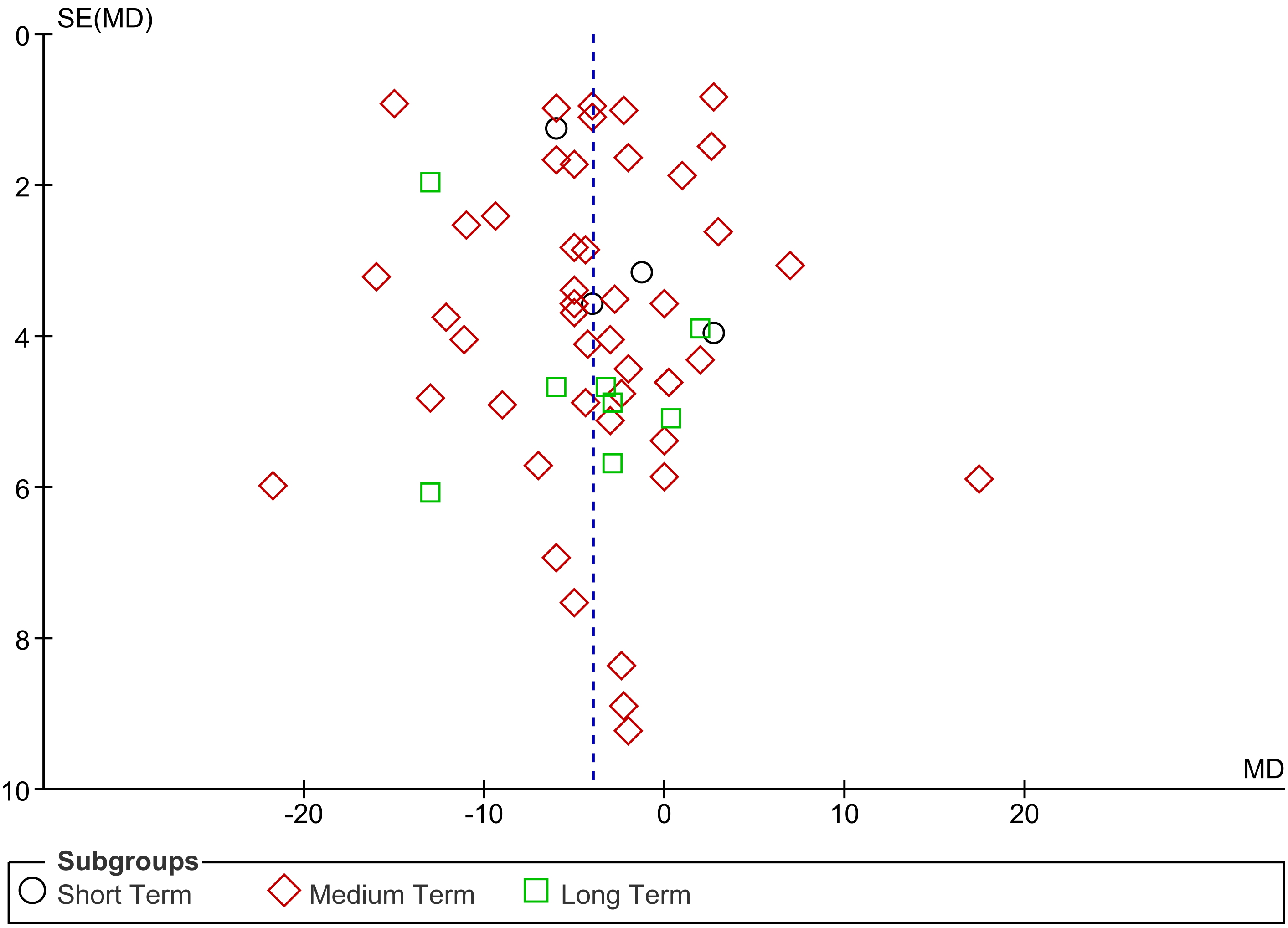


Fig 1. Funnel plot of studies reporting systolic blood pressure.

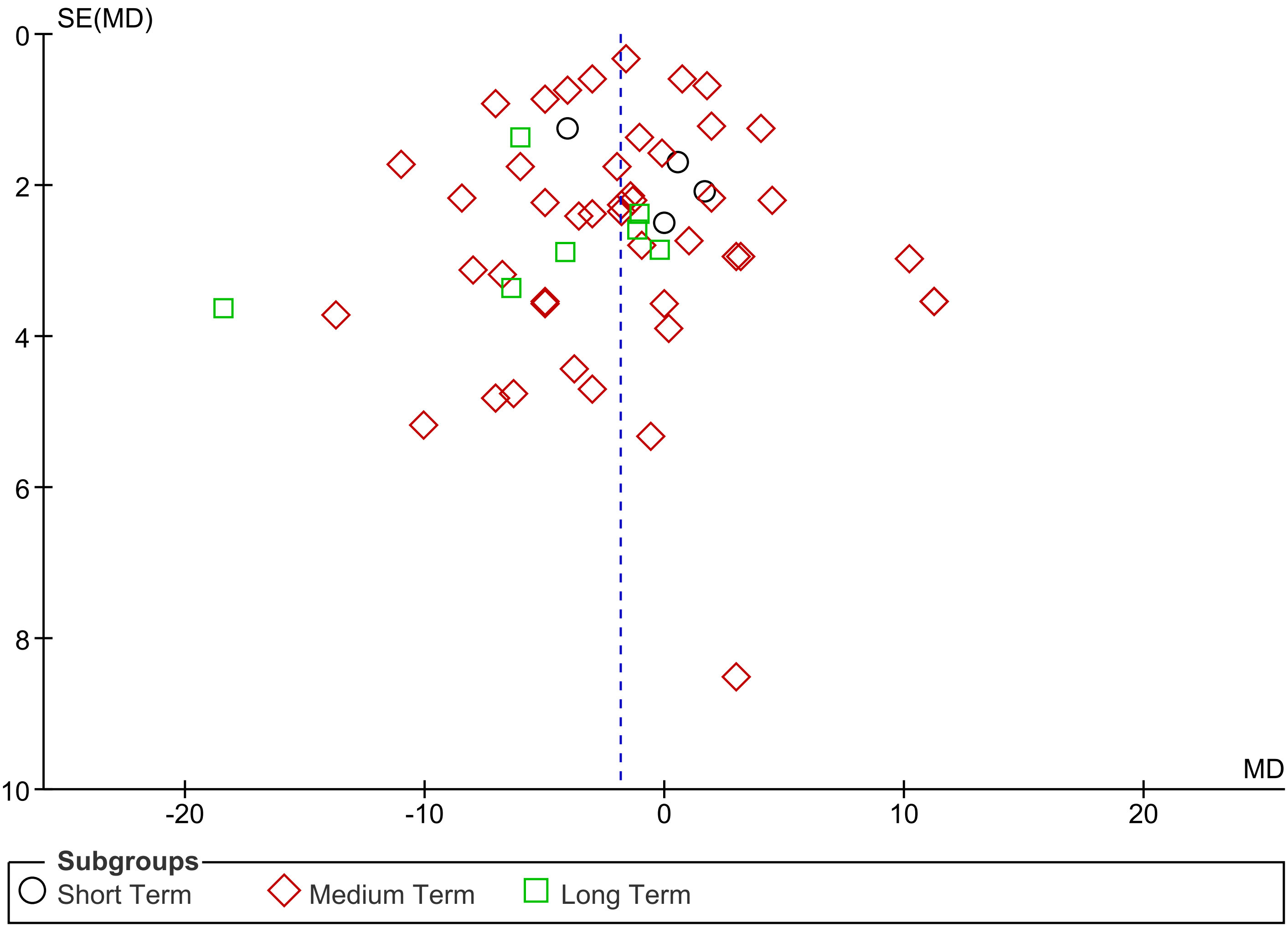


Fig 2. Funnel plot of studies reporting diastolic blood pressure.

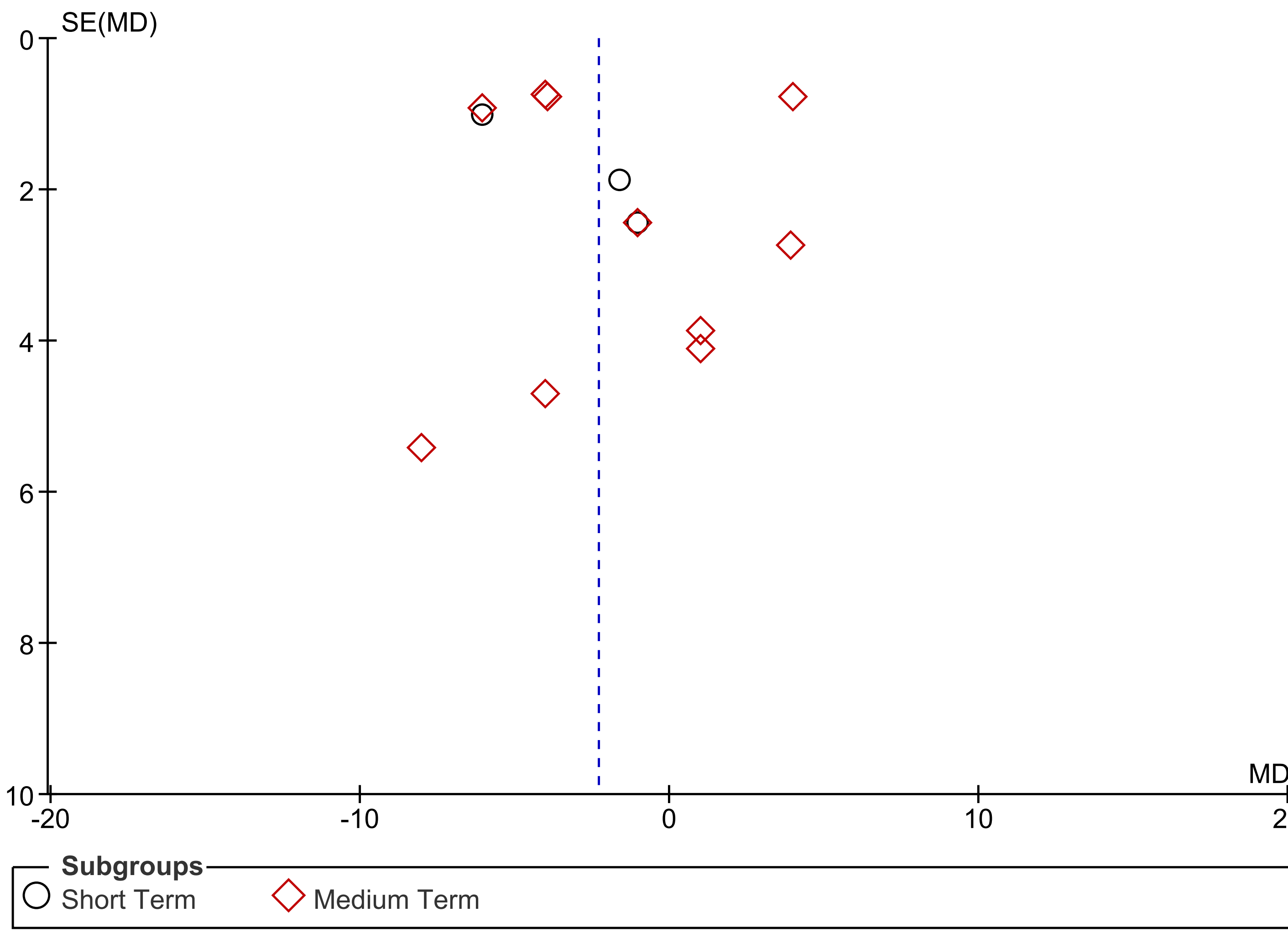


Fig 3. Funnel plot of studies reporting mean arterial pressure.

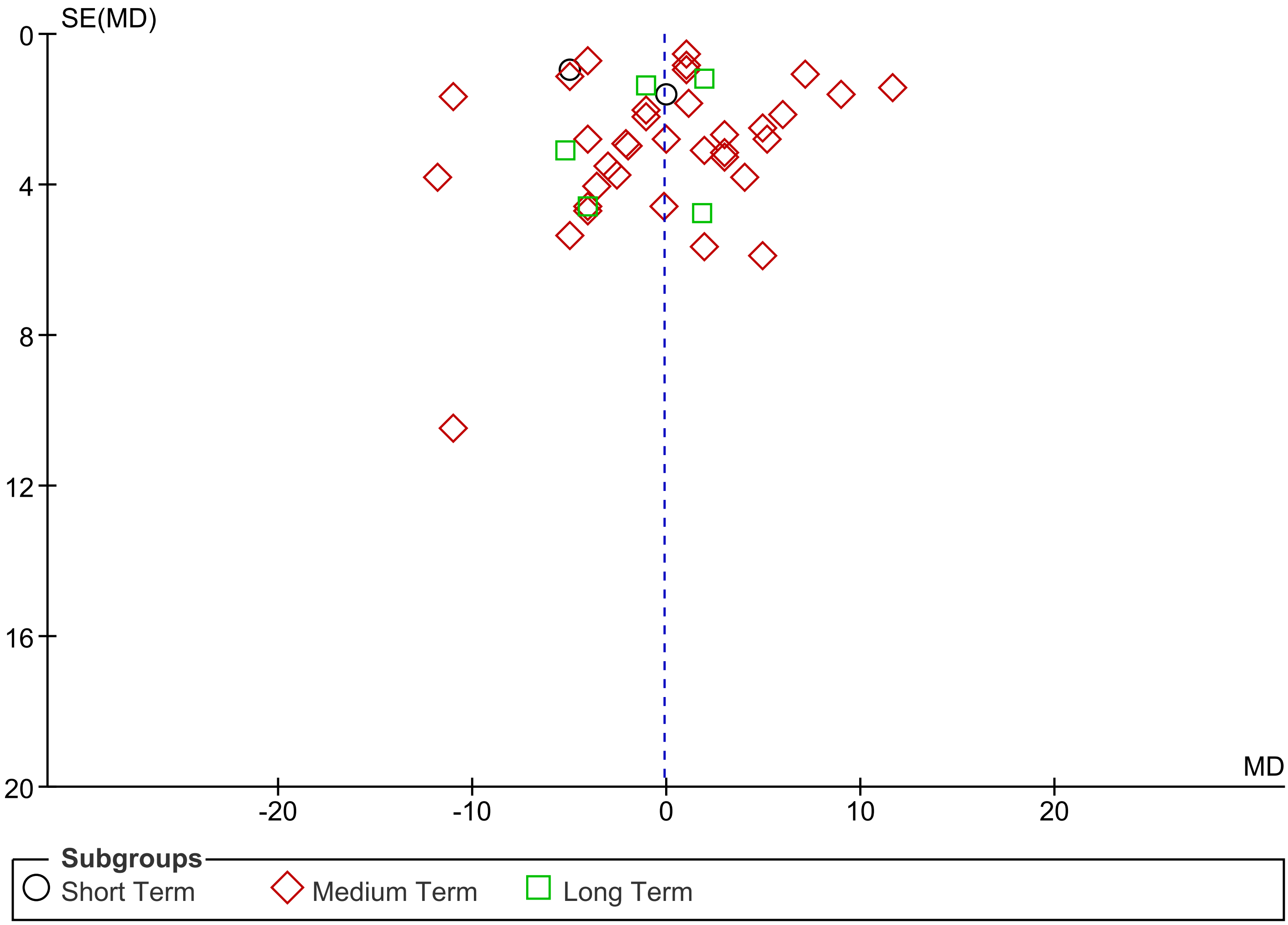


Fig 4. Funnel plot of studies reporting resting heart rate.

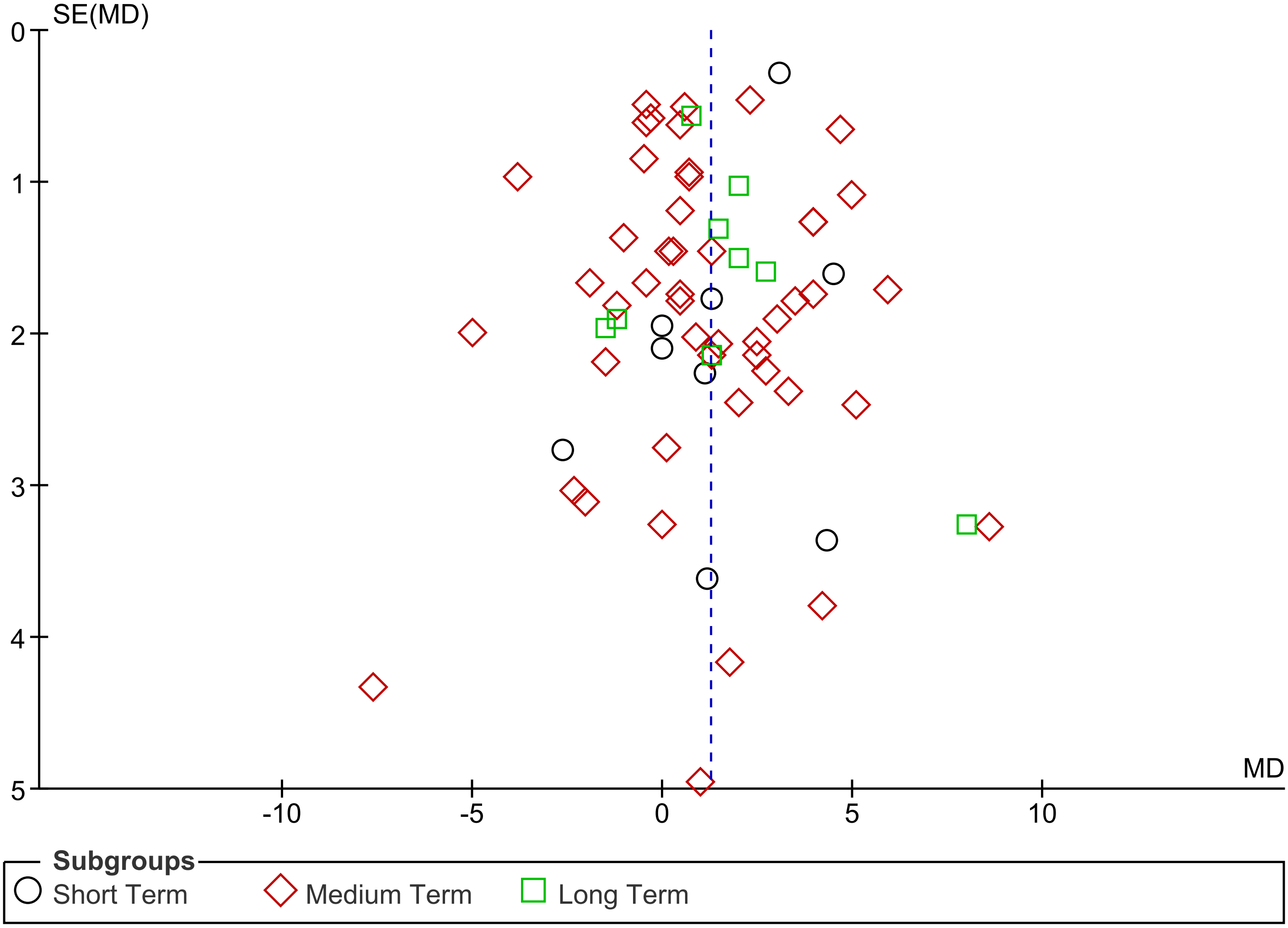


Fig 5. Funnel plot of studies reporting $\dot{V}O_2max$.

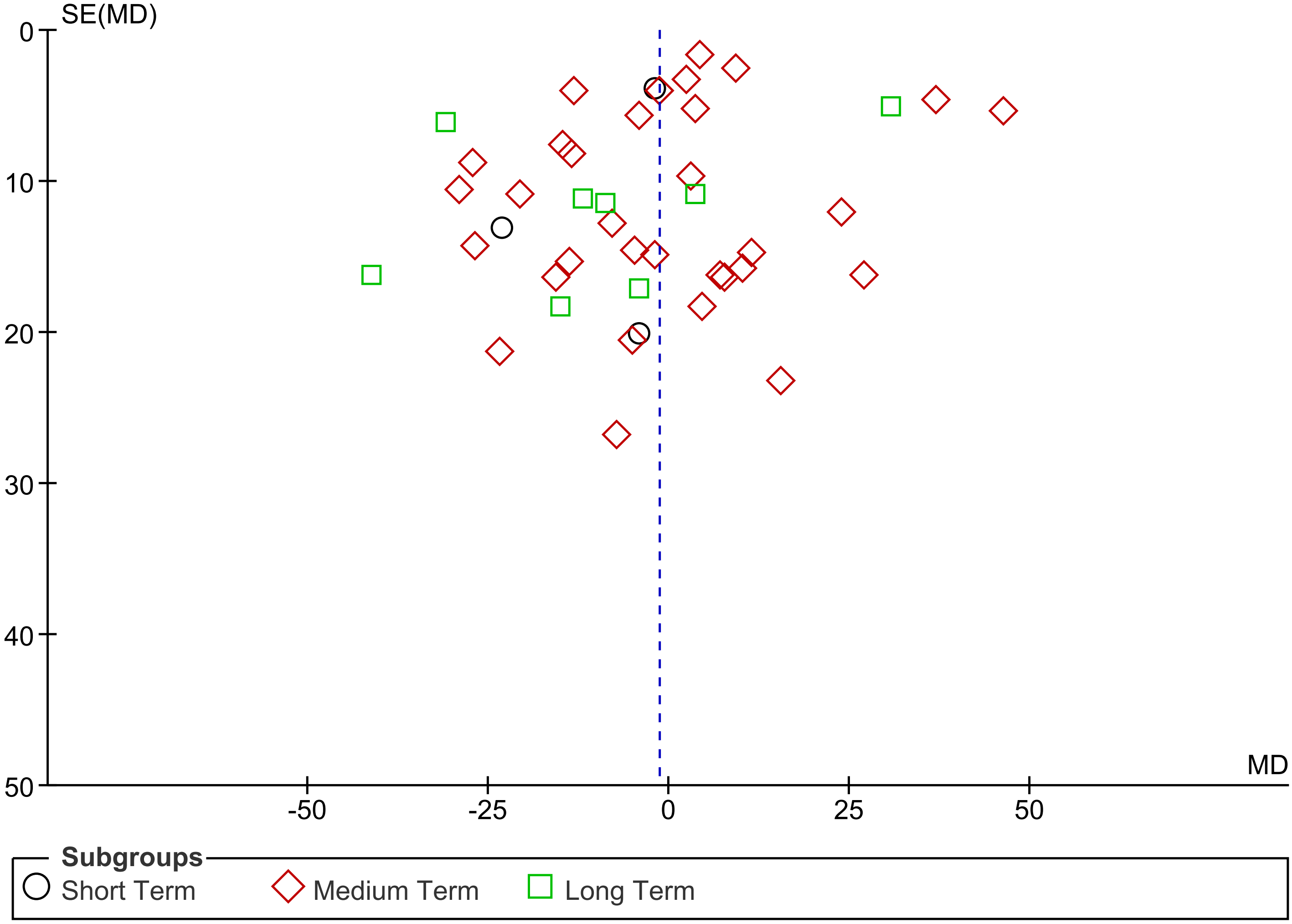


Fig 6. Funnel plot of studies reporting total cholesterol levels.

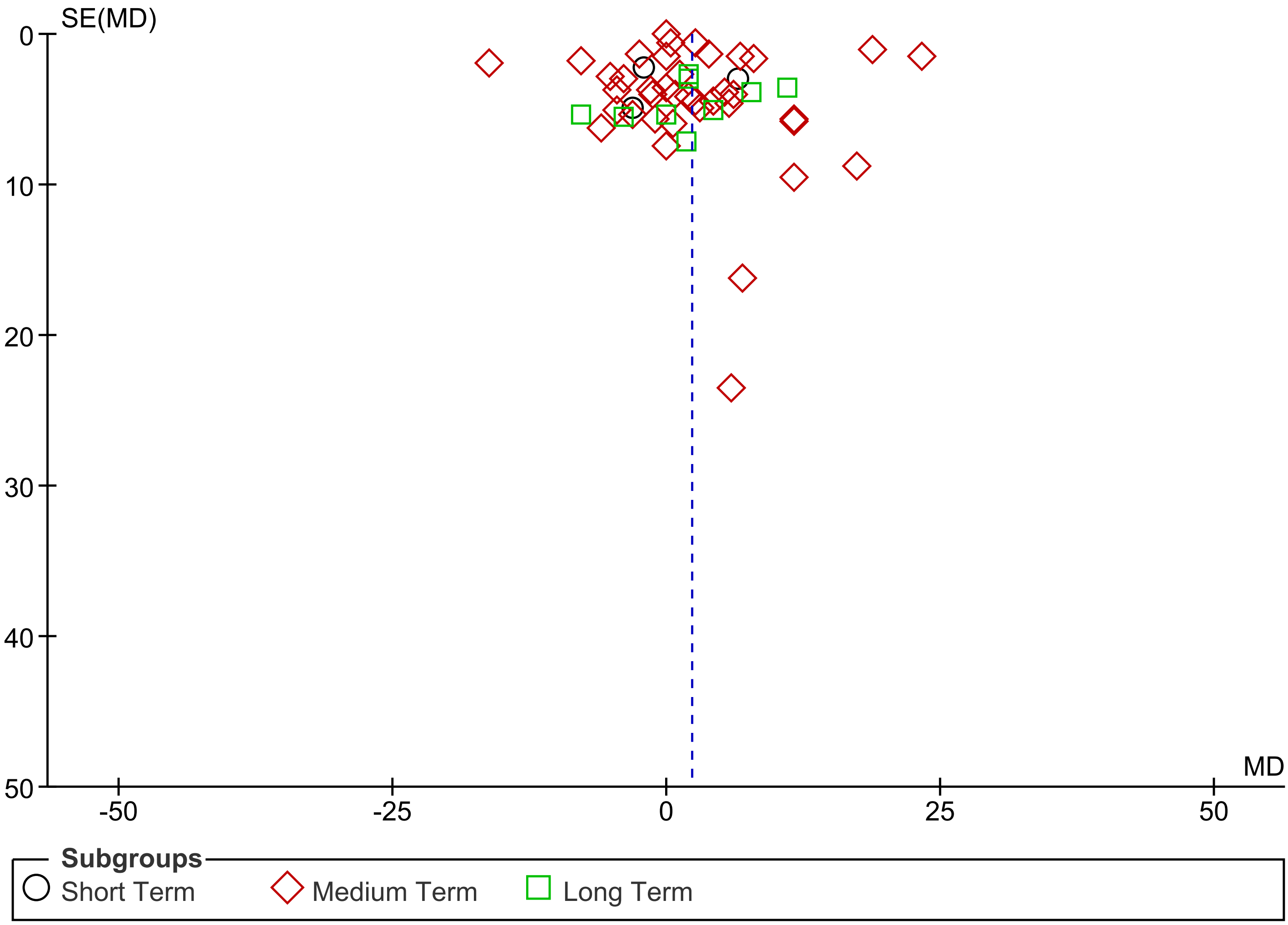


Fig 7. Funnel plot of studies reporting high density lipoprotein cholesterol levels.

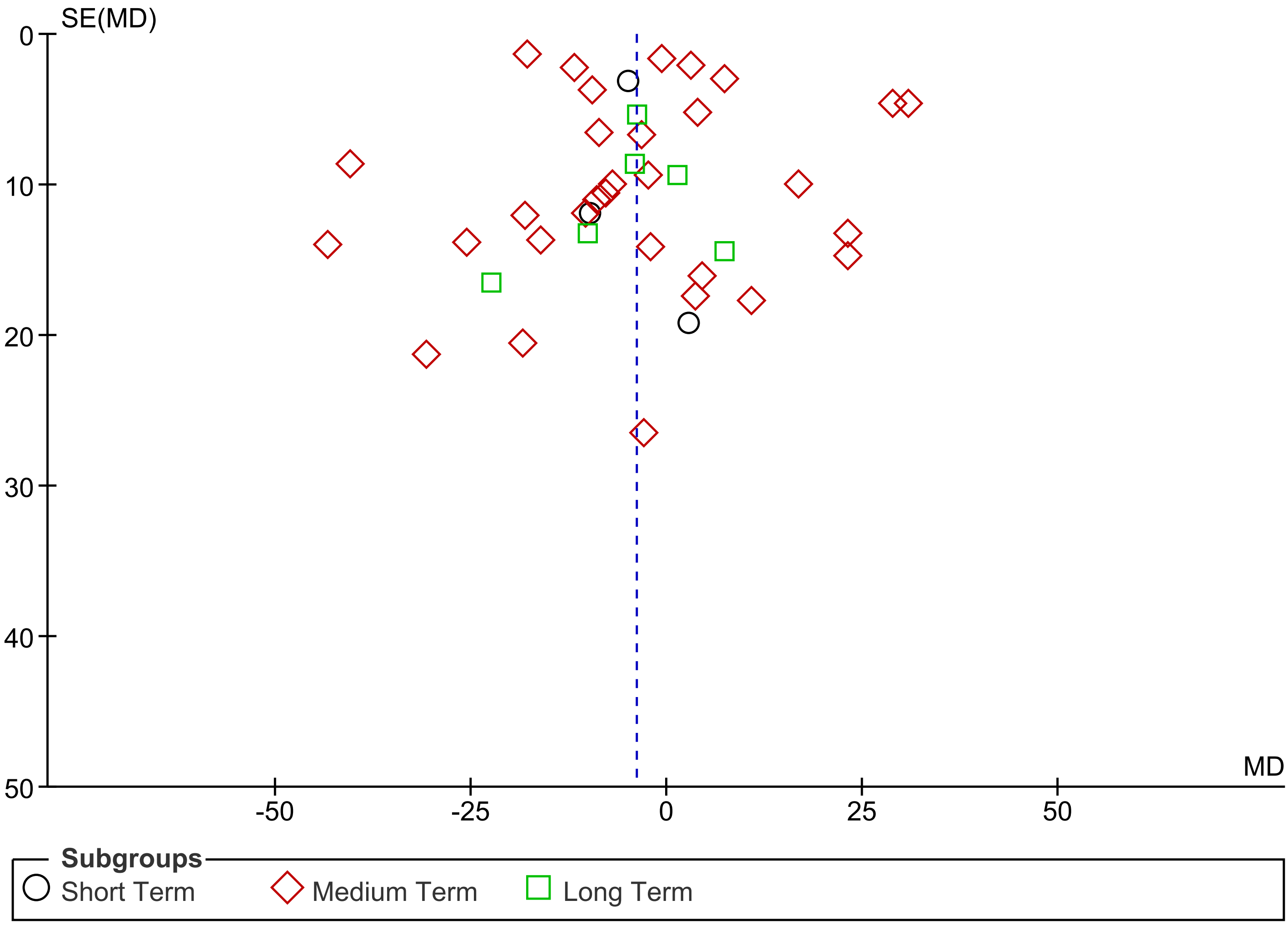


Fig 8. Funnel plot of studies reporting low density lipoprotein cholesterol levels.

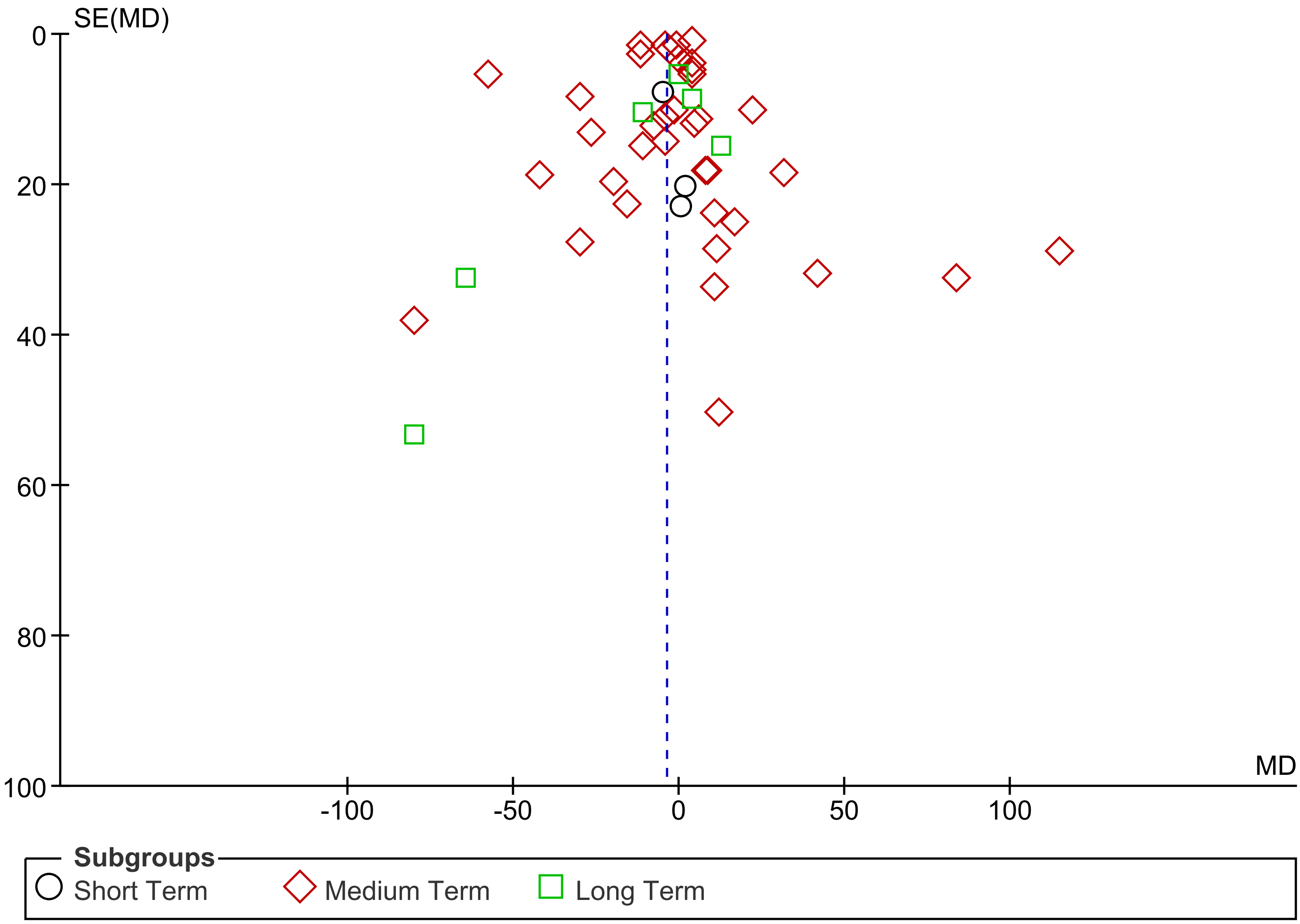


Fig 9. Funnel plot of studies reporting triglyceride levels.

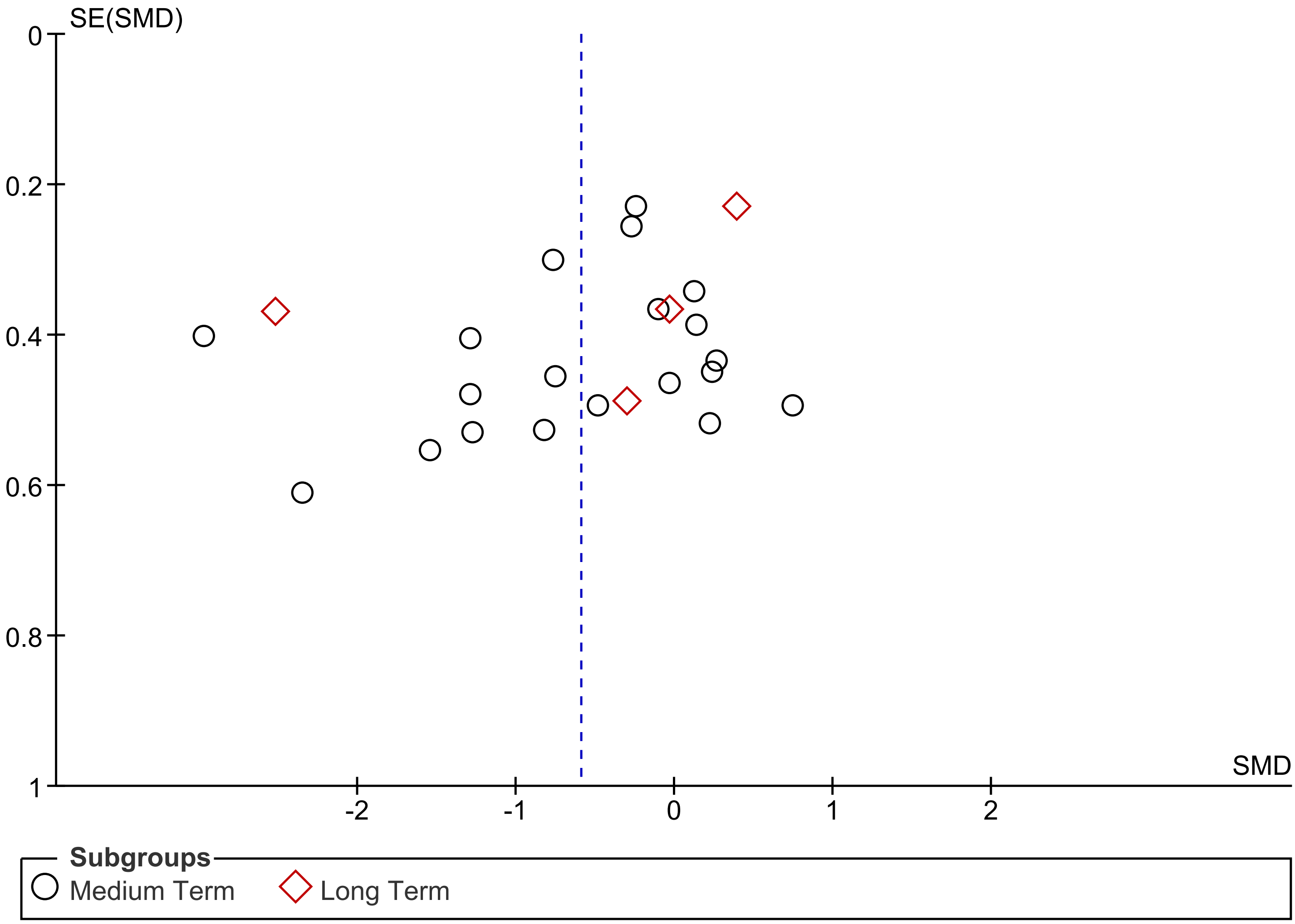


Fig 10. Funnel plot of studies reporting fasted insulin levels.

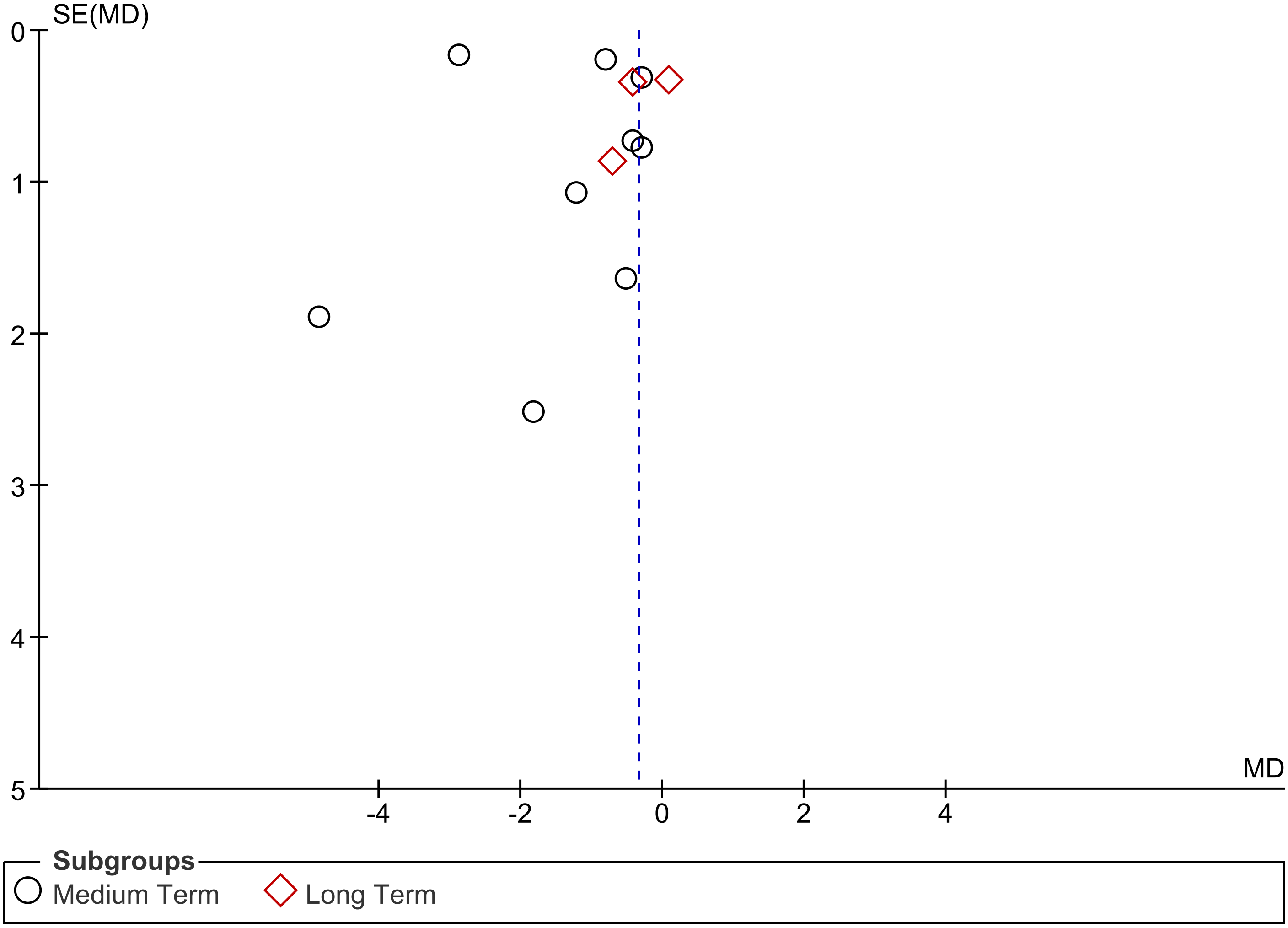


Fig 11. Funnel plot of studies reporting insulin resistance (HOMA-IR).

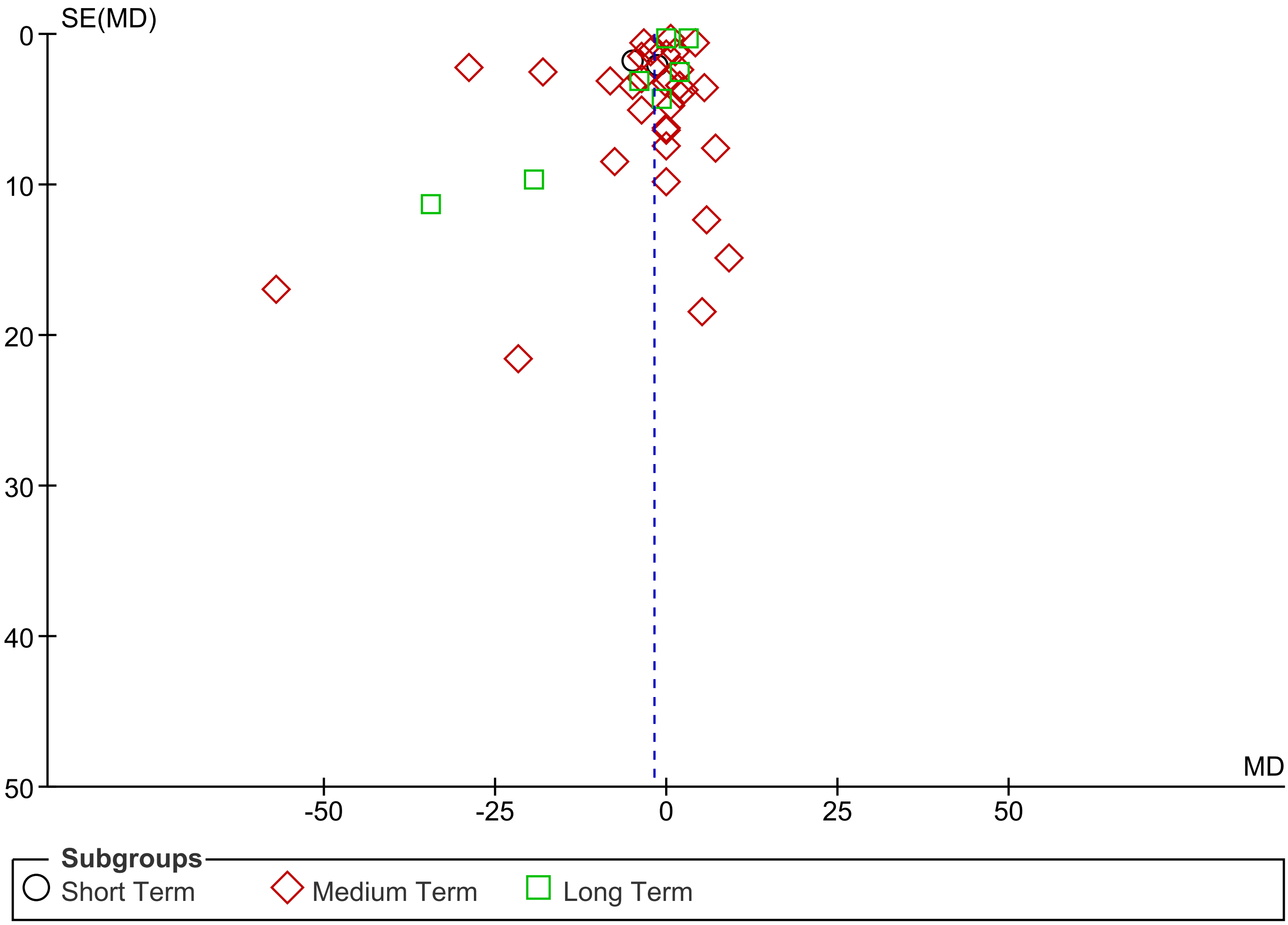


Fig 12. Funnel plot of studies reporting fasted glucose levels.

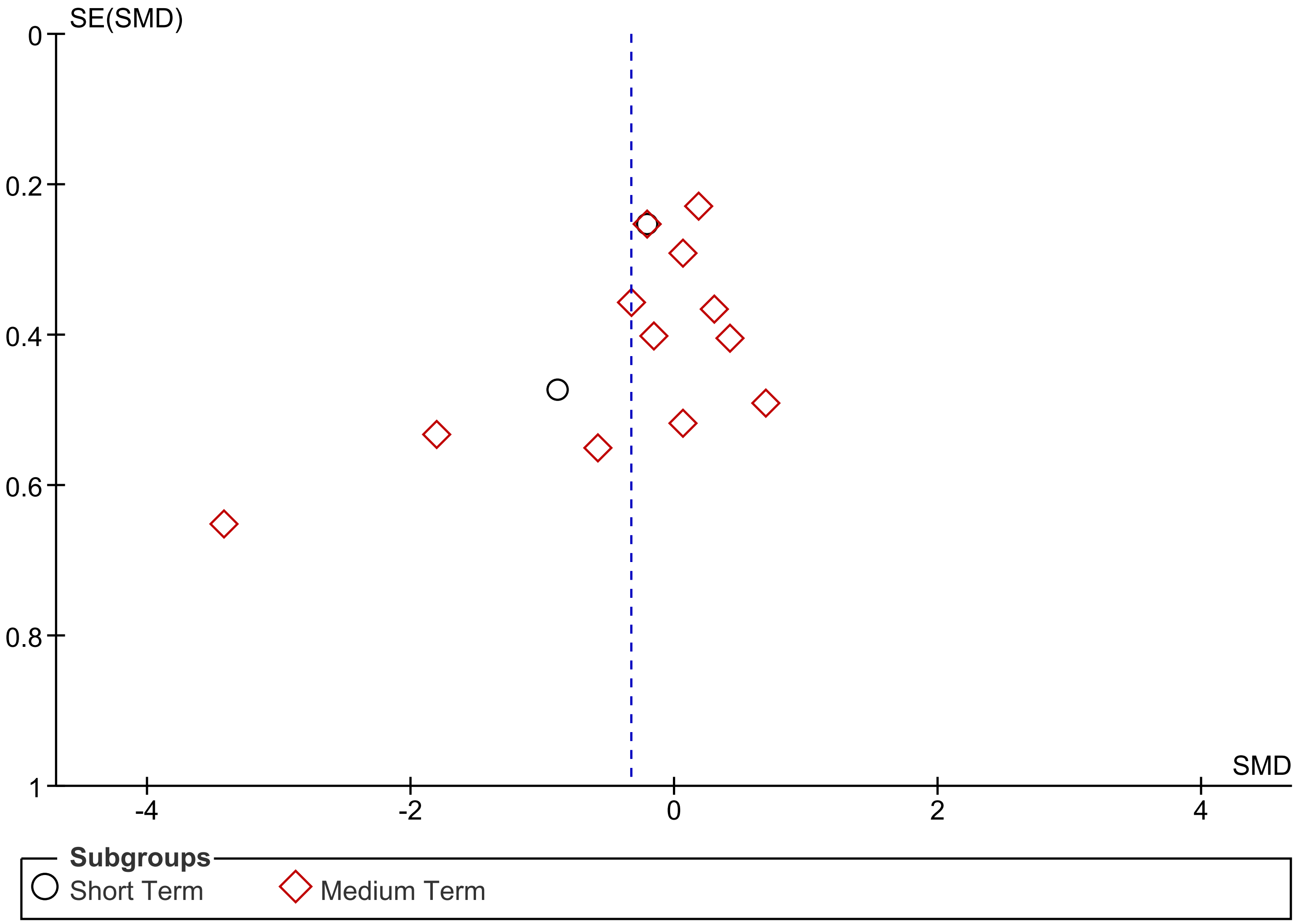
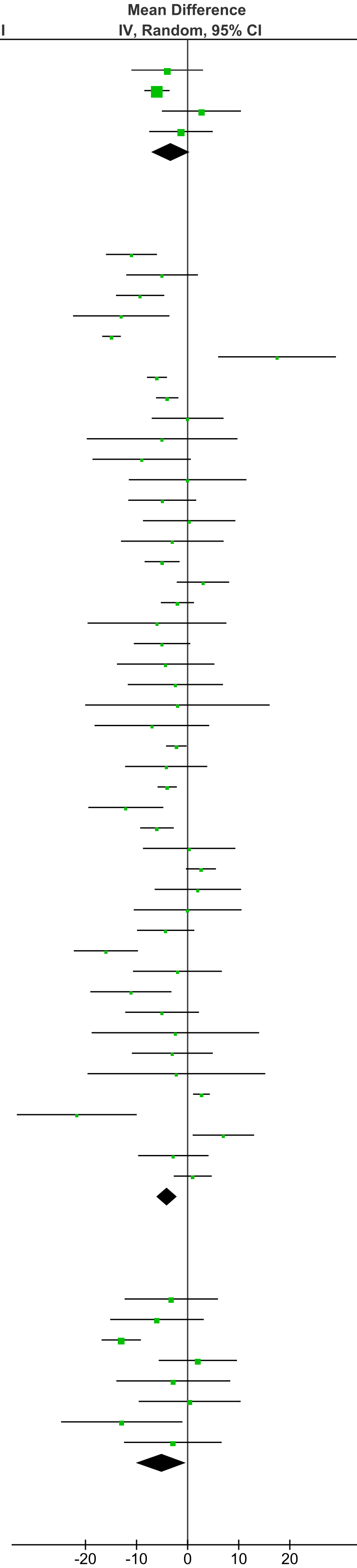


Fig 13. Funnel plot of studies reporting c-reactive protein levels.

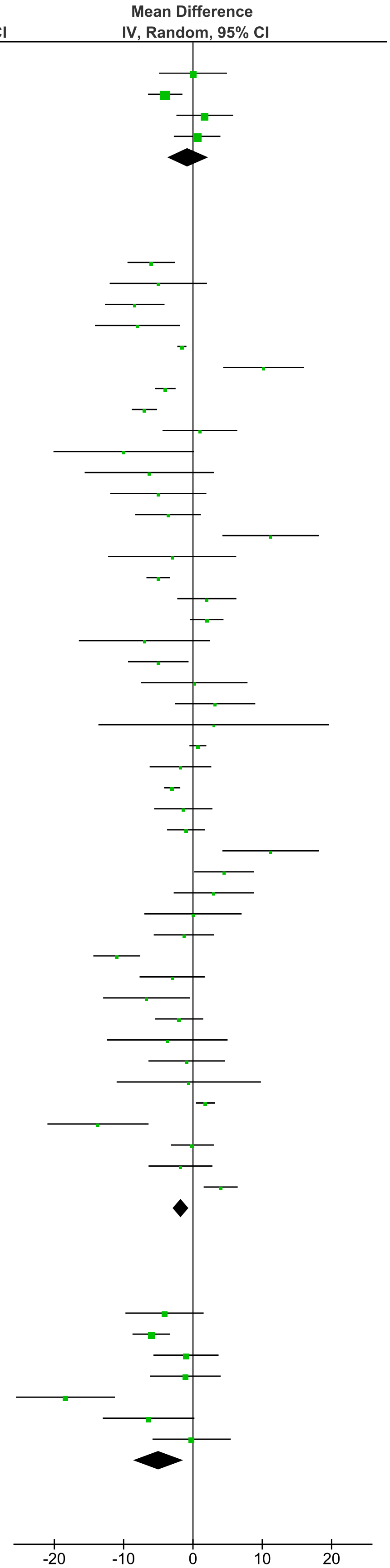
Study or Subgroup	Resistance Training Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
1.1.1 Short Term								
Badrov et al 2013 (IHG 5 days a week)	90	9	11	94	7	9	18.7%	-4.00 [-11.01, 3.01]
Figueroa et al 2012	112	2	5	118	2	5	43.1%	-6.00 [-8.48, -3.52]
Mota et al 2013	134.5	14.6	32	131.8	16.9	32	16.4%	2.70 [-5.04, 10.44]
Wiles et al 2010 (High intensity RT)	116.7	6.7	11	118	8.1	11	21.8%	-1.30 [-7.51, 4.91]
Subtotal (95% CI)			**59**			**57**	**100.0%**	**-3.17 [-6.95, 0.60]**
Heterogeneity: Tau² = 7.01; Chi² = 5.76, df = 3 (P = 0.12); I² = 48%								
Test for overall effect: Z = 1.65 (P = 0.10)								
1.1.2 Medium Term								
Arora et al 2009	118	5.1	9	129	6	10	2.6%	-11.00 [-15.99, -6.01]
Badrov et al 2013 (IHG 5 days a week)	91	9	11	96	7	9	2.2%	-5.00 [-12.01, 2.01]
Beck et al 2013	120.8	6.4	15	130.1	6.8	15	2.7%	-9.30 [-14.03, -4.57]
Beltran Valls et al 2014	116	12	13	129	11	10	1.8%	-13.00 [-22.44, -3.56]
Castaneda et al 2002	135.5	3.3	29	150.4	3.9	31	3.1%	-14.90 [-16.72, -13.08]
Conceicao et al 2013	130.8	16.6	10	113.3	8.4	10	1.5%	17.50 [5.97, 29.03]
DeVallance et al 2016 (Healthy)	110	2	16	116	3	12	3.1%	-6.00 [-7.96, -4.04]
DeVallance et al 2016 (Metabolic syndrome)	122	3	13	126	3	16	3.1%	-4.00 [-6.20, -1.80]
Dunstan et al 1998	127	9.9	11	127	6.3	10	2.2%	0.00 [-7.03, 7.03]
Elliott et al 2002	129	14	8	134	15	7	1.1%	-5.00 [-19.75, 9.75]
Fenkci et al 2006	114.7	10.7	17	123.7	17.2	17	1.8%	-9.00 [-18.63, 0.63]
Franklin et al 2015	121	10	10	121	14	8	1.5%	0.00 [-11.51, 11.51]
Gelecek et al 2012	108.12	8.68	24	113.09	13.27	21	2.3%	-4.97 [-11.62, 1.68]
Greenwood et al 2015	136	13.3	13	135.7	12.4	20	1.9%	0.30 [-8.74, 9.34]
Hallsworth et al 2011	133	4	9	136	14	8	1.7%	-3.00 [-13.05, 7.05]
Heffernan et al 2013	134	4	11	139	4	10	2.9%	-5.00 [-8.43, -1.57]
Hu et al 2009	135	12	48	132	9	21	2.6%	3.00 [-2.13, 8.13]
Kanegusuku et al 2011 (Constant velocity RT)	116	5	13	118	3	11	3.0%	-2.00 [-5.25, 1.25]
Karelis et al 2016	122	20	10	128	9	10	1.2%	-6.00 [-19.59, 7.59]
Kawano et al 2006	115	6.9	12	120	8	16	2.5%	-5.00 [-10.53, 0.53]
Levinger et al 2007 (High metabolic risk)	132.2	13	15	136.5	13.2	14	1.8%	-4.30 [-13.84, 5.24]
Levinger et al 2007 (Low metabolic risk)	112	8.2	10	114.4	12.6	10	1.8%	-2.40 [-11.72, 6.92]
Lovell et al 2009	137	24.2	12	139	20.8	12	0.8%	-2.00 [-20.05, 16.05]
McGuigan et al 2001	128	11	11	135	14	9	1.5%	-7.00 [-18.22, 4.22]
Mikesky et al 1994	138.8	3.8	25	141.01	3.8	30	3.1%	-2.21 [-4.23, -0.19]
Miura et al 2008 (RT 2 days a week)	118.3	13.4	25	122.5	14.9	23	2.0%	-4.20 [-12.24, 3.84]
Miyachi et al 2004	116	3	14	120	2	14	3.1%	-4.00 [-5.89, -2.11]
Mota et al 2013	120.2	11.8	32	132.3	17.6	32	2.2%	-12.10 [-19.44, -4.76]
Nybo et al 2010	121	4	8	127	3	11	2.9%	-6.00 [-9.29, -2.71]
O'Connor et al 2017	136	13.3	13	135.7	12.4	20	1.9%	0.30 [-8.74, 9.34]
Okamoto et al 2006 (Eccentric RT)	109.4	3.8	10	106.8	2.7	9	3.0%	2.60 [-0.34, 5.54]
Okamoto et al 2011	116	11	13	114	11	13	2.0%	2.00 [-6.46, 10.46]
Okamoto et al 2013 (Low before high intensity RT)	115	11	10	115	13	10	1.6%	0.00 [-10.55, 10.55]
Plotnikoff et al 2010	122.4	8.6	27	126.7	10.7	21	2.5%	-4.30 [-9.91, 1.31]
Shenoy et al 2009	117	4.6	9	133	8.9	10	2.4%	-16.00 [-22.28, -9.72]
Sigal et al 2009	129	26	64	131	24	63	1.9%	-2.00 [-10.70, 6.70]
Sillanpaa et al 2012	119.1	13.2	15	130.21	8.2	14	2.1%	-11.11 [-19.05, -3.17]
Simons & Andel 2006	124	11	19	129	12	20	2.2%	-5.00 [-12.22, 2.22]
Stebbings et al 2013 (Female)	111.3	9.8	7	113.7	7.5	1	1.0%	-2.40 [-18.79, 13.99]
Stebbings et al 2013 (Male)	117.1	6.3	5	120.1	7.1	6	2.1%	-3.00 [-10.92, 4.92]
Stensvold et al 2010	139.9	16.9	11	142.1	24.1	11	0.9%	-2.20 [-19.59, 15.19]
Tanimoto et al 2009 (High intensity RT)	110.3	1.3	12	107.6	2.6	12	3.2%	2.70 [1.06, 4.34]
Tsutsumi et al 1997 (High intensity/low volume)	103.7	17.4	14	125.4	14.1	14	1.5%	-21.70 [-33.43, -9.97]
Venojarvi et al 2013	4.1	14.2	37	-2.9	12.6	40	2.4%	7.00 [0.98, 13.02]
Wiles et al 2010 (High intensity RT)	116.3	6.9	11	119.1	9.4	11	2.3%	-2.80 [-9.69, 4.09]
Yoshizawa et al 2009	117	5	11	116	4	12	2.9%	1.00 [-2.72, 4.72]
Subtotal (95% CI)			**742**			**714**	**100.0%**	**-4.02 [-5.92, -2.11]**
Heterogeneity: Tau² = 29.19; Chi² = 325.48, df = 45 (P < 0.00001); I² = 86%								
Test for overall effect: Z = 4.14 (P < 0.0001)								
1.1.3 Long Term								
Colado et al 2009	129.7	13.9	21	132.9	11.2	10	12.3%	-3.20 [-12.34, 5.94]
McGuigan et al 2001	131	8	11	137	12	9	12.2%	-6.00 [-15.15, 3.15]
Olson 2006	104	7	15	117	3	15	18.7%	-13.00 [-16.85, -9.15]
Sigal et al 2009	131	23	64	129	21	63	14.0%	2.00 [-5.66, 9.66]
Van de Rest et al 2014	147.19	20	27	150	23.351	31	10.2%	-2.81 [-13.97, 8.35]
Vincent et al 2002 (High intensity RT)	129.7	9	24	129.3	19	16	11.3%	0.40 [-9.58, 10.38]
Wanderley et al 2013	123.3	14.2	11	136.2	18.7	19	9.5%	-12.90 [-24.78, -1.02]
Yavari et al 2012	118.4	12.2	15	121.3	14.4	15	11.8%	-2.90 [-12.45, 6.65]
Subtotal (95% CI)			**188**			**178**	**100.0%**	**-5.08 [-10.04, -0.13]**
Heterogeneity: Tau² = 30.39; Chi² = 19.46, df = 7 (P = 0.007); I² = 64%								
Test for overall effect: Z = 2.01 (P = 0.04)								



Test for subgroup differences: Chi² = 0.37, df = 2 (P = 0.83), I² = 0%

Fig 14. Short-, medium-, long-term effects of resistance exercise training on systolic blood pressure as standardised mean difference and 95% CI.

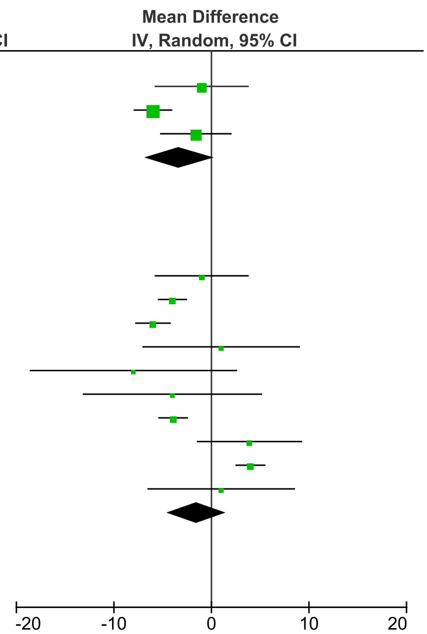
Study or Subgroup	Resistance Training Mean	Resistance Training SD	Resistance Training Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
1.3.1 Short Term								
Badrov et al 2013 (IHG 5 days a week)	54	5	11	54	6	9	19.1%	0.00 [-4.91, 4.91]
Figueroa et al 2012	62	2	5	66	2	5	31.6%	-4.00 [-6.48, -1.52]
Mota et al 2013	76	9.2	32	74.3	7.4	32	22.8%	1.70 [-2.39, 5.79]
Wiles et al 2010 (High intensity RT)	67	4.4	11	66.4	3.6	11	26.6%	0.60 [-2.76, 3.96]
Subtotal (95% CI)			**59**			**57**	**100.0%**	**-0.72 [-3.66, 2.22]**
Heterogeneity: Tau² = 5.53; Chi² = 8.10, df = 3 (P = 0.04); I² = 63%								
Test for overall effect: Z = 0.48 (P = 0.63)								
1.3.2 Medium Term								
Arora et al 2009	77	4.1	9	83	3.5	10	2.8%	-6.00 [-9.45, -2.55]
Badrov et al 2013 (IHG 5 days a week)	91	9	11	96	7	9	1.6%	-5.00 [-12.01, 2.01]
Beck et al 2013	72.3	6.4	15	80.7	5.6	15	2.4%	-8.40 [-12.70, -4.10]
Beltran Valls et al 2014	76	8	13	84	7	10	1.8%	-8.00 [-14.14, -1.86]
Castaneda et al 2002	69.2	1.2	29	70.8	1.4	31	3.7%	-1.60 [-2.26, -0.94]
Conceicao et al 2013	88.2	5.45	10	78	7.7	10	1.9%	10.20 [4.35, 16.05]
DeVallance et al 2016 (Healthy)	69	2	16	73	2	12	3.5%	-4.00 [-5.50, -2.50]
DeVallance et al 2016 (Metabolic syndrome)	70	2	13	77	3	16	3.4%	-7.00 [-8.83, -5.17]
Dunstan et al 1998	73	6.3	11	72	6.3	10	2.0%	1.00 [-4.40, 6.40]
Elliott et al 2002	67	11	8	77	9	7	1.0%	-10.00 [-20.13, 0.13]
Fenkci et al 2006	74.4	9	7	80.7	8.8	7	1.1%	-6.30 [-15.62, 3.02]
Franklin et al 2015	71	8	10	76	7	8	1.6%	-5.00 [-11.94, 1.94]
Gelecek et al 2012	70.2	8.64	24	73.8	7.56	21	2.3%	-3.60 [-8.33, 1.13]
Greenwood et al 2015	84.7	10.7	13	73.5	8.7	20	1.6%	11.20 [4.25, 18.15]
Hallsworth et al 2011	86	8	9	89	11	8	1.1%	-3.00 [-12.24, 6.24]
Heffernan et al 2013	77	2	11	82	2	10	3.4%	-5.00 [-6.71, -3.29]
Hu et al 2009	75	9	48	73	8	21	2.5%	2.00 [-2.26, 6.26]
Kanegusuku et al 2011 (Constant velocity RT)	75	3	13	73	3	11	3.2%	2.00 [-0.41, 4.41]
Karelis et al 2016	74	13	10	81	8	10	1.1%	-7.00 [-16.46, 2.46]
Kawano et al 2006	68	6.9	12	73	4	16	2.4%	-5.00 [-9.37, -0.63]
Levinger et al 2007 (High metabolic risk)	90.8	12.7	15	90.6	8	14	1.4%	0.20 [-7.47, 7.87]
Levinger et al 2007 (Low metabolic risk)	76.4	6.9	10	73.2	6.3	10	1.9%	3.20 [-2.59, 8.99]
Lovell et al 2009	82	20.8	12	79	20.8	12	0.4%	3.00 [-13.64, 19.64]
Mikesky et al 1994	78.01	2.3	25	77.3	2.3	30	3.5%	0.71 [-0.51, 1.93]
Miura et al 2008 (RT 2 days a week)	69	7.2	25	70.8	8.4	23	2.4%	-1.80 [-6.24, 2.64]
Miyachi et al 2004	70	2	14	73	1	14	3.6%	-3.00 [-4.17, -1.83]
Mota et al 2013	72.4	9.3	32	73.8	7.8	32	2.5%	-1.40 [-5.61, 2.81]
Nybo et al 2010	75	3	8	76	3	11	3.1%	-1.00 [-3.73, 1.73]
O'Connor et al 2017	84.7	10.7	13	73.5	8.7	20	1.6%	11.20 [4.25, 18.15]
Okamoto et al 2006 (Eccentric RT)	67.3	4.8	10	62.8	4.8	9	2.4%	4.50 [0.18, 8.82]
Okamoto et al 2011	64	7	13	61	8	13	1.9%	3.00 [-2.78, 8.78]
Okamoto et al 2013 (Low before high intensity RT)	65	8	10	65	8	10	1.6%	0.00 [-7.01, 7.01]
Plotnikoff et al 2010	73.9	7.3	27	75.2	7.9	21	2.4%	-1.30 [-5.66, 3.06]
Shenoy et al 2009	74	3.7	9	85	3.8	10	2.8%	-11.00 [-14.37, -7.63]
Sigal et al 2009	78	14	64	81	13	63	2.3%	-3.00 [-7.70, 1.70]
Sillanpaa et al 2012	77.3	9.8	15	84	7.3	14	1.8%	-6.70 [-12.96, -0.44]
Simons & Andel 2006	68	6	19	70	5	20	2.8%	-2.00 [-5.48, 1.48]
Stebbings et al 2013 (Female)	68.8	6.5	7	72.5	6.4	3	1.2%	-3.70 [-12.40, 5.00]
Stebbings et al 2013 (Male)	69.8	3.8	5	70.7	5.5	6	2.0%	-0.90 [-6.42, 4.62]
Stensvold et al 2010	88.9	11.2	11	89.5	13.6	11	0.9%	-0.60 [-11.01, 9.81]
Tanimoto et al 2009 (High intensity RT)	61.8	1.9	12	60	1.5	12	3.5%	1.80 [0.43, 3.17]
Tsutsumi et al 1997 (High intensity/low volume)	62.3	9.9	14	76	9.8	14	1.5%	-13.70 [-21.00, -6.40]
Venojarvi et al 2013	-2.8	6.4	37	-2.7	7.5	40	2.9%	-0.10 [-3.21, 3.01]
Wiles et al 2010 (High intensity RT)	65.8	3.2	11	67.6	7.1	11	2.3%	-1.80 [-6.40, 2.80]
Yoshizawa et al 2009	75	3	11	71	3	12	3.2%	4.00 [1.55, 6.45]
Subtotal (95% CI)			**721**			**697**	**100.0%**	**-1.73 [-2.88, -0.57]**
Heterogeneity: Tau² = 9.38; Chi² = 263.07, df = 44 (P < 0.00001); I² = 83%								
Test for overall effect: Z = 2.94 (P = 0.003)								
1.3.3 Long Term								
Colado et al 2009	76.9	6.3	21	81	8	10	13.8%	-4.10 [-9.74, 1.54]
Olson 2006	62	5	15	68	2	15	18.5%	-6.00 [-8.73, -3.27]
Sigal et al 2009	78	14	64	79	13	63	15.4%	-1.00 [-5.70, 3.70]
Van de Rest et al 2014	73.89	10.631	27	75	8.952	31	14.7%	-1.11 [-6.21, 3.99]
Vincent et al 2002 (High intensity RT)	61.1	10.1	24	79.5	12	16	11.5%	-18.40 [-25.53, -11.27]
Wanderley et al 2013	67.4	8.2	11	73.8	10	19	12.3%	-6.40 [-13.01, 0.21]
Yavari et al 2012	75.8	8.5	15	76	7.2	15	13.8%	-0.20 [-5.84, 5.44]
Subtotal (95% CI)			**177**			**169**	**100.0%**	**-4.93 [-8.58, -1.28]**
Heterogeneity: Tau² = 16.87; Chi² = 22.07, df = 6 (P = 0.001); I² = 73%								
Test for overall effect: Z = 2.64 (P = 0.008)								



Test for subgroup differences: Chi² = 3.34, df = 2 (P = 0.19), I² = 40.2%

Fig 15. Short-, medium-, long-term effects of resistance exercise training on diastolic blood pressure as standardised mean difference and 95% CI.

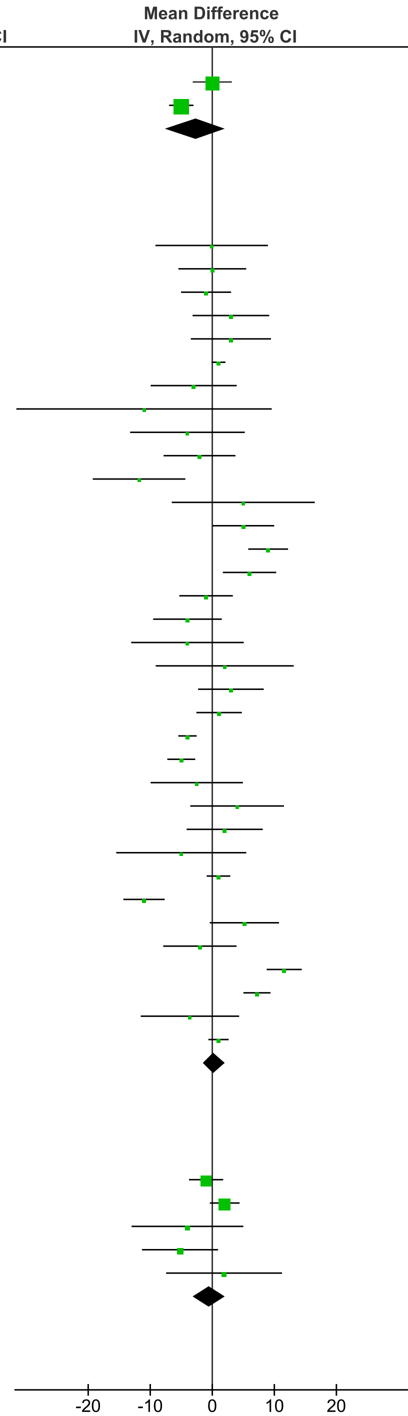
Study or Subgroup	Resistance Training Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
1.2.1 Short Term								
Badrov et al 2013 (IHG 5 days a week)	68	6	11	69	5	9	25.7%	-1.00 [-5.82, 3.82]
Figueroa et al 2012	96	3	13	102	2	12	42.3%	-6.00 [-7.98, -4.02]
Wiles et al 2010 (High intensity RT)	86.8	3.4	11	88.4	5.2	11	32.0%	-1.60 [-5.27, 2.07]
Subtotal (95% CI)			**35**			**32**	**100.0%**	**-3.31 [-6.86, 0.25]**
Heterogeneity: Tau² = 6.76; Chi² = 6.61, df = 2 (P = 0.04); I² = 70%								
Test for overall effect: Z = 1.82 (P = 0.07)								
1.2.2 Medium Term								
Badrov et al 2013 (IHG 5 days a week)	68	6	11	69	5	9	10.4%	-1.00 [-5.82, 3.82]
DeVallance et al 2016 (Healthy)	84	2	16	88	2	12	13.6%	-4.00 [-5.50, -2.50]
DeVallance et al 2016 (Metabolic syndrome)	89	2	13	95	3	16	13.4%	-6.00 [-7.83, -4.17]
Egana et al 2010	98	6	8	97	10	8	7.0%	1.00 [-7.08, 9.08]
Elliott et al 2002	88	11	8	96	10	7	5.2%	-8.00 [-18.63, 2.63]
Hallsworth et al 2011	105	6	9	109	12	8	6.1%	-4.00 [-13.19, 5.19]
Kemmler et al 2016	-3.84	3.9	38	0.09	2.87	40	13.6%	-3.93 [-5.46, -2.40]
Okamoto et al 2006 (Eccentric RT)	82.7	6.2	10	78.8	5.8	9	9.7%	3.90 [-1.50, 9.30]
Okamoto et al 2011	84	2	13	80	2	13	13.6%	4.00 [2.46, 5.54]
Okamoto et al 2013 (Low before high intensity RT)	84	7	10	83	10	10	7.5%	1.00 [-6.57, 8.57]
Subtotal (95% CI)			**136**			**132**	**100.0%**	**-1.57 [-4.60, 1.46]**
Heterogeneity: Tau² = 17.01; Chi² = 97.16, df = 9 (P < 0.00001); I² = 91%								
Test for overall effect: Z = 1.02 (P = 0.31)								



Test for subgroup differences: Chi² = 0.53, df = 1 (P = 0.47), I² = 0%

Fig 16. Short- and medium-term effects of resistance exercise training on mean arterial pressure as standardised mean difference and 95% CI.

Study or Subgroup	Resistance Training Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
1.4.1 Short Term								
Badrov et al 2013 (IHG 5 days a week)	63	3	11	63	4	9	46.8%	0.00 [-3.16, 3.16]
Figueroa et al 2012	76	1	5	81	2	5	53.2%	-5.00 [-6.96, -3.04]
Subtotal (95% CI)			**16**			**14**	**100.0%**	**-2.66 [-7.55, 2.23]**
Heterogeneity: Tau² = 10.70; Chi² = 6.95, df = 1 (P = 0.008); I² = 86%								
Test for overall effect: Z = 1.07 (P = 0.29)								
1.4.2 Medium Term								
Almenning et al 2015	58.3	11.7	8	58.4	6.2	9	2.0%	-0.10 [-9.16, 8.96]
Arora et al 2009	84	7.8	9	84	3.2	10	3.0%	0.00 [-5.47, 5.47]
Badrov et al 2013 (IHG 5 days a week)	64	4	11	65	5	9	3.4%	-1.00 [-5.03, 3.03]
Beck et al 2013	61	10	15	58	7	15	2.7%	3.00 [-3.18, 9.18]
Beltran Valls et al 2014	69	6	13	66	9	10	2.7%	3.00 [-3.46, 9.46]
Castaneda et al 2002	72	1	29	71	3	31	4.0%	1.00 [-0.12, 2.12]
Dunstan et al 1998	76	8.3	11	79	7.9	10	2.5%	-3.00 [-9.93, 3.93]
Egana et al 2010	62	21	8	73	21	8	0.6%	-11.00 [-31.58, 9.58]
Franklin et al 2015	70	11	10	74	9	8	2.0%	-4.00 [-13.24, 5.24]
Gelecek et al 2012	78.41	6.04	24	80.47	12.31	21	2.9%	-2.06 [-7.85, 3.73]
Greenwood et al 2015	76.3	11.8	13	88.1	8.7	20	2.4%	-11.80 [-19.26, -4.34]
Hallsworth et al 2011	69	16	9	64	7	8	1.5%	5.00 [-6.52, 16.52]
Hu et al 2009	70	9	48	65	10	21	3.1%	5.00 [0.02, 9.98]
Kanegusuku et al 2011 (Constant velocity RT)	87	4	13	78	4	11	3.6%	9.00 [5.79, 12.21]
Karavirta et al 2009	59	8	25	53	6	16	3.3%	6.00 [1.70, 10.30]
Karavirta et al 2013	61	6.5	26	62	7.4	17	3.3%	-1.00 [-5.31, 3.31]
Kawano et al 2006	53	6.9	12	57	8	16	2.9%	-4.00 [-9.53, 1.53]
Kemi et al 2011	62	10	12	66	12	11	2.0%	-4.00 [-13.07, 5.07]
Lovell et al 2009	68	13.9	12	66	13.9	12	1.6%	2.00 [-9.12, 13.12]
Mikesky et al 1994	70.5	9	25	67.5	11	30	3.0%	3.00 [-2.29, 8.29]
Miura et al 2008 (RT 2 days a week)	69.5	5.7	25	68.4	7.1	23	3.5%	1.10 [-2.56, 4.76]
Miyachi et al 2004	53	2	14	57	2	14	4.0%	-4.00 [-5.48, -2.52]
Nybo et al 2010	56	2	8	61	3	11	3.8%	-5.00 [-7.25, -2.75]
Okamoto et al 2006 (Eccentric RT)	64.2	9.7	10	66.7	6.7	9	2.4%	-2.50 [-9.94, 4.94]
Okamoto et al 2011	66	7	13	62	12	13	2.4%	4.00 [-3.55, 11.55]
Okamoto et al 2013 (Low before high intensity RT)	64	7	10	62	7	10	2.8%	2.00 [-4.14, 8.14]
Schiffer et al 2011	82	10	7	87	10	7	1.7%	-5.00 [-15.48, 5.48]
Schmidt et al 2014	60	2	9	59	2	8	3.9%	1.00 [-0.90, 2.90]
Shenoy et al 2009	74	3.8	10	85	3.8	10	3.6%	-11.00 [-14.33, -7.67]
Sillanpaa et al 2012	56.6	8.8	15	51.43	6.41	14	2.9%	5.17 [-0.41, 10.75]
Simons & Andel 2006	75	6	19	77	12	20	2.8%	-2.00 [-7.91, 3.91]
Stebbings et al 2013 (Female)	73.2	2.32	7	61.61	1.98	3	3.7%	11.59 [8.77, 14.41]
Stebbings et al 2013 (Male)	70.54	1.28	5	63.34	2.34	6	3.9%	7.20 [5.02, 9.38]
Tsutsumi et al 1997 (High intensity/low volume)	71.8	11	14	75.4	10.4	14	2.3%	-3.60 [-11.53, 4.33]
Yoshizawa et al 2009	63	2	11	62	2	12	4.0%	1.00 [-0.64, 2.64]
Subtotal (95% CI)			**510**			**467**	**100.0%**	**0.35 [-1.44, 2.13]**
Heterogeneity: Tau² = 20.34; Chi² = 266.11, df = 34 (P < 0.00001); I² = 87%								
Test for overall effect: Z = 0.38 (P = 0.70)								
1.4.3 Long Term								
Madden et al 2006	-2	3.9	15	-1	3.1	10	34.2%	-1.00 [-3.75, 1.75]
Schmidt et al 2014	61	3	9	59	2	8	37.5%	2.00 [-0.40, 4.40]
Vincent et al 2002 (High intensity RT)	80	13	24	84	15	16	7.4%	-4.00 [-13.00, 5.00]
Wanderley et al 2013	60.3	8.4	11	65.5	8	19	13.9%	-5.20 [-11.33, 0.93]
Yavari et al 2012	81.5	13.2	15	79.6	12.9	15	7.0%	1.90 [-7.44, 11.24]
Subtotal (95% CI)			**74**			**68**	**100.0%**	**-0.48 [-3.12, 2.17]**
Heterogeneity: Tau² = 3.35; Chi² = 6.83, df = 4 (P = 0.15); I² = 41%								
Test for overall effect: Z = 0.35 (P = 0.72)								



Test for subgroup differences: Chi² = 1.37, df = 2 (P = 0.51), I² = 0%

Fig 17. Short-, medium-, long-term effects of resistance exercise training on resting heart rate as standardised mean difference and 95% CI.

	Resistance Training			Control				Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
1.14.1 Short Term								
Edge et al 2006	45.2	5.2	8	44	8.8	8	3.2%	1.20 [-5.88, 8.28]
Hautala et al 2006	36	7	45	36	7	18	9.3%	0.00 [-3.83, 3.83]
Husby et al 2009	29.8	6.3	12	25.5	9.8	12	3.7%	4.30 [-2.29, 10.89]
Kim et al 2011 (Traditional RT)	40.1	7.6	13	42.7	5.1	8	5.2%	-2.60 [-8.04, 2.84]
Maiorana et al 2011	15.8	4.3	11	14.5	3.8	10	10.9%	1.30 [-2.16, 4.76]
Parr et al 2009	18.7	6	9	17.6	3	8	7.4%	1.10 [-3.34, 5.54]
Rana et al 2008 (Traditional RT)	39.2	3.9	10	34.7	2.9	8	12.5%	4.50 [1.36, 7.64]
Vona et al 2009	25.9	1.4	54	22.8	1.6	50	39.4%	3.10 [2.52, 3.68]
Zambom et al 2015	19.6	5.4	15	19.6	4.7	9	8.3%	0.00 [-4.11, 4.11]
Subtotal (95% CI)			**177**			**131**	**100.0%**	**2.07 [0.75, 3.39]**
Heterogeneity: Tau² = 1.07; Chi² = 11.35, df = 8 (P = 0.18); I² = 30%								
Test for overall effect: Z = 3.06 (P = 0.002)								
1.14.2 Medium Term								
Ades et al 1996	25	6	12	23	6	12	1.4%	2.00 [-2.80, 6.80]
Ahmadizad et al 2007	29.1	7.8	8	20.5	5	8	0.9%	8.60 [2.18, 15.02]
Almenning et al 2015	40.2	8.5	8	36	6.9	9	0.7%	4.20 [-3.22, 11.62]
Andersen et al 2008	33	8	18	35	7	8	1.0%	-2.00 [-8.10, 4.10]
Andersen et al 2014	30.8	1.4	9	30.1	2.4	8	3.0%	0.70 [-1.20, 2.60]
Asad et al 2012	32.49	4.04	9	31.02	5	10	1.7%	1.47 [-2.60, 5.54]
Azarbayjani et al 2014	40.9	2.6	10	35.9	2.3	10	2.8%	5.00 [2.85, 7.15]
Beltran Valls et al 2014	20.6	1.4	13	17.85	7	10	1.5%	2.75 [-1.65, 7.15]
Broeder et al 1992	49.7	1.5	13	49.2	2.1	19	3.5%	0.50 [-0.75, 1.75]
Camargo et al 2008	43.1	4	7	37.2	2	6	2.0%	5.90 [2.53, 9.27]
Courneya et al 2007	24.2	6.1	77	23.5	5.4	73	3.1%	0.70 [-1.14, 2.54]
DeLima et al 2012 (Daily undulating periodisation)	31.42	4.39	10	32.88	4.76	8	1.6%	-1.46 [-5.74, 2.82]
Franklin et al 2015	34.2	2.3	10	31.7	5.7	8	1.6%	2.50 [-1.70, 6.70]
Garcia-Lopez et al 2007	33.5	1.6	11	37.3	2.4	8	3.0%	-3.80 [-5.71, -1.89]
Greenwood et al 2015	16.8	3.9	13	12.8	3	20	2.6%	4.00 [1.51, 6.49]
Hagerman et al 2000	23.3	4.8	19	22	6.4	12	1.6%	1.30 [-2.92, 5.52]
Heffernan et al 2013	23	4	11	28	5	10	1.7%	-5.00 [-8.90, -1.10]
Hendrickson et al 2010	38.9	1.1	18	38.3	1.4	10	3.6%	0.60 [-0.41, 1.61]
Hiatt et al 1994	14.4	4.2	9	13.9	3.5	10	2.0%	0.50 [-3.00, 4.00]
Hoff et al 2007	11	0.9	6	11.3	1.1	6	3.6%	-0.30 [-1.44, 0.84]
Hu et al 2009	38.7	6	48	38.4	5.4	21	2.3%	0.30 [-2.57, 3.17]
Jay et al 2011	2.9	4.9	17	4.8	5	18	2.1%	-1.90 [-5.18, 1.38]
Kaikkonen et al 2000	40.4	4.8	27	39.1	5.9	27	2.3%	1.30 [-1.57, 4.17]
Kanegusuku et al 2011 (Constant velocity RT)	23.3	1.7	13	23.7	1.3	11	3.5%	-0.40 [-1.60, 0.80]
Karelis et al 2016	25.3	7	10	20.2	3.5	10	1.3%	5.10 [0.25, 9.95]
Kell & Asmundson 2009	34.9	8.3	9	33.1	9.3	9	0.6%	1.80 [-6.34, 9.94]
Larose et al 2010	21.95	4.7	63	22.4	4.7	60	3.2%	-0.45 [-2.11, 1.21]
LeMura et al 2000	33.6	2.9	11	33.1	2.8	12	2.7%	0.50 [-1.83, 2.83]
Levinger et al 2007 (High metabolic risk)	24.1	6.1	15	23.2	4.9	15	1.7%	0.90 [-3.06, 4.86]
Levinger et al 2007 (Low metabolic risk)	25.8	7.6	12	22.5	3.4	13	1.4%	3.30 [-1.38, 7.98]
Libardi et al 2011	35.4	4.6	12	31.9	4.3	13	2.0%	3.50 [0.00, 7.00]
Lovell et al 2009	26.1	5.3	12	23.1	3.9	12	1.8%	3.00 [-0.72, 6.72]
Mahdirejei et al 2014	32.08	1.41	9	27.4	1.39	9	3.5%	4.68 [3.39, 5.97]
Maiorana et al 1997	23.1	4.9	12	22.6	3.8	14	2.0%	0.50 [-2.91, 3.91]
Maiorana et al 2011	16.4	1.1	10	14.1	1.1	12	3.7%	2.30 [1.38, 3.22]
Marcinik et al 1991	44.8	7.3	10	47.1	5.6	8	1.0%	-2.30 [-8.26, 3.66]
Mosti et al 2013	31.18	3.19	8	32.38	4.01	8	1.9%	-1.20 [-4.75, 2.35]
Mosti et al 2014	48.9	4.1	14	49.3	4.9	15	2.1%	-0.40 [-3.68, 2.88]
Nikseresht et al 2014	45.1	3.2	12	41.1	4.7	10	2.0%	4.00 [0.57, 7.43]
Nybo et al 2010	37.9	3.3	8	38.9	2.4	11	2.5%	-1.00 [-3.69, 1.69]
O'Connor et al 2017	16.8	3.9	13	12.8	3	20	2.6%	4.00 [1.51, 6.49]
Oliveira et al 2013	45.9	5.4	12	44.9	11.5	6	0.5%	1.00 [-8.70, 10.70]
Romero-Areanas et al 2007 (High RT circuit)	35.6	7.9	16	43.2	10.2	7	0.6%	-7.60 [-16.09, 0.89]
Sillanpaa et al 2012	30.56	6.3	53	30.4	6.9	34	2.3%	0.16 [-2.71, 3.03]
Stensvold et al 2010	33.1	4.3	11	33.1	9.9	11	0.9%	0.00 [-6.38, 6.38]
Tsutsumi et al 1997 (High intensity/low volume)	23	5.4	14	22.9	8.8	14	1.2%	0.10 [-5.31, 5.51]
Weiser & Haber 2007	21.91	3.64	14	19.4	5.71	10	1.7%	2.51 [-1.51, 6.53]
Yoshizawa et al 2009	26.5	1.2	11	26.9	1.2	12	3.6%	-0.40 [-1.38, 0.58]
Subtotal (95% CI)			**767**			**687**	**100.0%**	**1.07 [0.38, 1.76]**
Heterogeneity: Tau² = 3.17; Chi² = 160.15, df = 47 (P < 0.00001); I² = 71%								
Test for overall effect: Z = 3.02 (P = 0.002)								
1.14.3 Long Term								
Fatouros et al 2005 (High intensity 80-85% 1RM)	18.3	2.3	14	16.3	2.6	10	14.4%	2.00 [-0.01, 4.01]
Hagberg et al 1989	23.3	4.8	19	22	6.4	12	3.4%	1.30 [-2.92, 5.52]
Madden et al 2006	0.2	1.9	15	-0.6	1.1	15	43.4%	0.80 [-0.31, 1.91]
Panton et al 1990	23.3	4.8	20	22	6.4	12	3.4%	1.30 [-2.89, 5.49]
Poehlman et al 2000	36.6	5	17	37.8	6.6	20	4.3%	-1.20 [-4.94, 2.54]
Poehlman et al 2002	37.2	5.08	16	38.7	6.5	19	4.1%	-1.50 [-5.34, 2.34]
Pollock et ak 1991	23.3	4.8	20	22	6.4	12	3.4%	1.30 [-2.89, 5.49]
Segal et al 2009	29.1	6.6	40	27.6	5.1	41	9.0%	1.50 [-1.07, 4.07]
Strasser et al 2009	19.64	5.22	15	16.9	3.14	14	6.2%	2.74 [-0.37, 5.85]
Vincent et al 2002 (High intensity RT)	24.4	5.8	22	22.4	3.4	16	6.9%	2.00 [-0.94, 4.94]
Yavari et al 2012	35.9	10.7	15	27.9	6.7	15	1.5%	8.00 [1.61, 14.39]
Subtotal (95% CI)			**213**			**186**	**100.0%**	**1.22 [0.44, 2.00]**
Heterogeneity: Tau² = 0.04; Chi² = 10.22, df = 10 (P = 0.42); I² = 2%								
Test for overall effect: Z = 3.06 (P = 0.002)								
Test for subgroup differences: Chi² = 1.74, df = 2 (P = 0.42), I² = 0%								

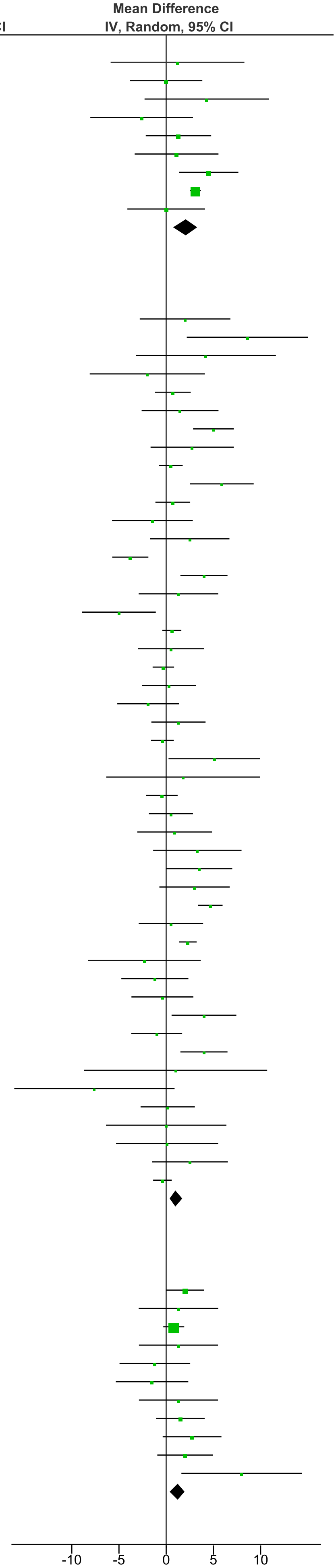


Fig 18. Short-, medium-, long-term effects of resistance exercise training on V̇O2max as standardised mean difference and 95% CI.

Study or Subgroup	Resistance Training Mean	Resistance Training SD	Resistance Training Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Fixed, 95% CI
Almenning et al 2015	6.2	1.4	8	4.9	1.9	9	20.7%	1.30 [-0.28, 2.88]
Beck et al 2013	8.3	4.1	15	5.85	3.96	15	6.2%	2.45 [-0.43, 5.33]
Franklin et al 2015	9.8	1.6	10	8	3.3	8	8.3%	1.80 [-0.69, 4.29]
Kwon et al 2011	5.6	2.8	12	4	1.9	15	15.0%	1.60 [-0.25, 3.45]
Okamoto et al 2009a (Eccentric RT)	15.4	2.4	10	14	2	10	13.7%	1.40 [-0.54, 3.34]
Okamoto et al 2011	11.8	1.9	13	9.9	1.1	13	36.1%	1.90 [0.71, 3.09]
Total (95% CI)			**68**			**70**	**100.0%**	**1.69 [0.97, 2.41]**

Heterogeneity: Chi² = 0.72, df = 5 (P = 0.98); I² = 0%
Test for overall effect: Z = 4.61 (P < 0.00001)

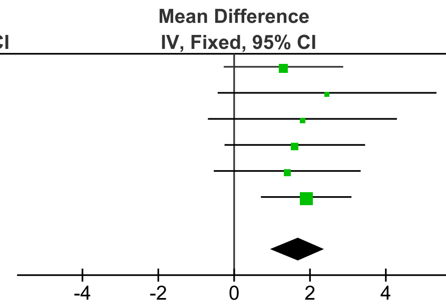
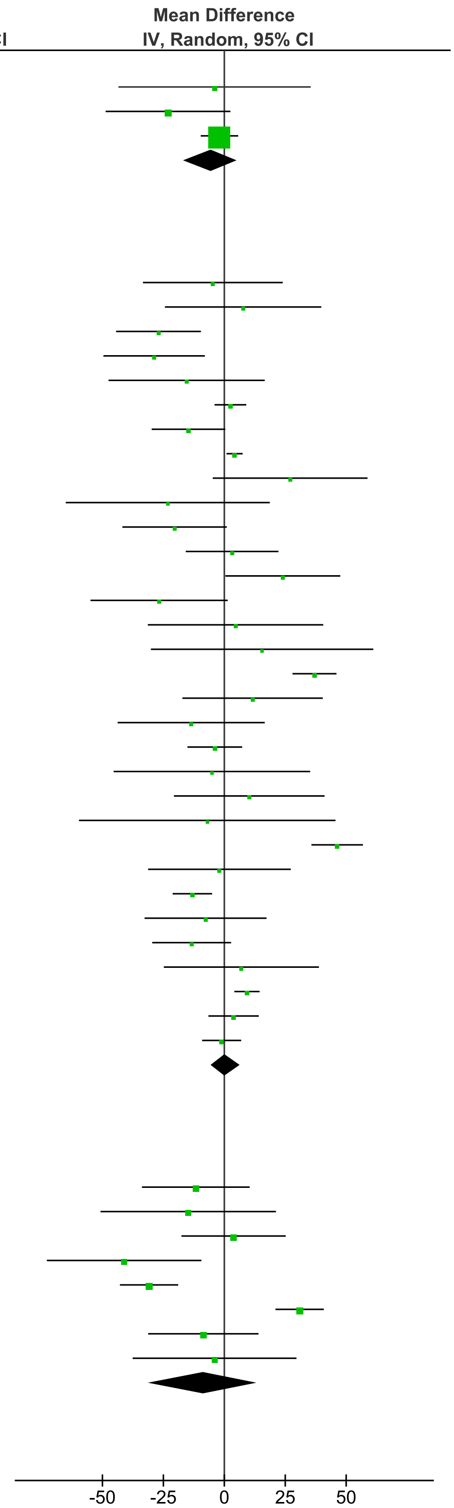


Fig 19. The effects of resistance exercise training on flow mediated dilatation as standardised mean difference and 95% CI.

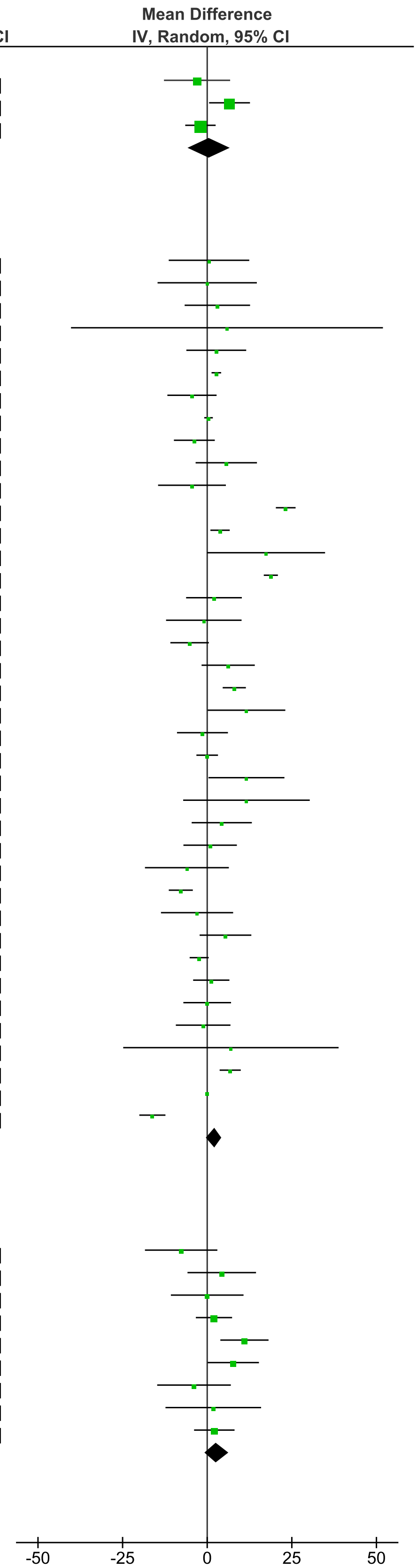
	Resistance Training			Control				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
1.6.1 Short Term								
Manning et al 1991	195	36	16	199	44.1	6	7.3%	-4.00 [-43.45, 35.45]
Vatani et al 2011 (High intensity RT)	150.8	25.1	10	173.9	32.8	10	16.1%	-23.10 [-48.70, 2.50]
Vona et al 2009	163	21	54	165	19	50	76.5%	-2.00 [-9.69, 5.69]
Subtotal (95% CI)			**80**			**66**	**100.0%**	**-5.55 [-16.58, 5.48]**
Heterogeneity: Tau² = 25.99; Chi² = 2.39, df = 2 (P = 0.30); I² = 16%								
Test for overall effect: Z = 0.99 (P = 0.32)								
1.6.2 Medium Term								
Afshar et al 2010	126.86	22.62	7	131.57	31.41	7	2.4%	-4.71 [-33.38, 23.96]
Almenning et al 2015	177.61	15.4	8	169.9	46.3	9	2.2%	7.71 [-24.37, 39.79]
Arora et al 2009	163	15.4	9	190	22.9	10	3.7%	-27.00 [-44.40, -9.60]
Augusto Libardi et al 2012 (Female)	183.21	27.06	12	212	24.9	12	3.3%	-28.79 [-49.60, -7.98]
Augusto Libardi et al 2012 (Male)	168.39	38.65	13	183.85	44.48	13	2.2%	-15.46 [-47.49, 16.57]
Azarbayjani et al 2014	169	8.76	10	166.5	5.79	10	4.9%	2.50 [-4.01, 9.01]
Boardley et al 2007	178.6	23.6	31	193.3	38.1	35	3.9%	-14.70 [-29.81, 0.41]
Castaneda et al 2002	185.7	6.2	29	181.5	6.9	31	5.1%	4.20 [0.88, 7.52]
Christensen et al 2014	231.6	42.4	13	204.6	38.61	12	2.2%	27.00 [-4.76, 58.76]
Elliott et al 2002	229.3	42.1	8	252.5	40.5	7	1.5%	-23.20 [-65.05, 18.65]
Fahlman et al 2002	162.2	27.1	15	182.6	32.5	15	3.2%	-20.40 [-41.81, 1.01]
Fenkci et al 2006	192.8	32.8	17	189.6	22.9	17	3.5%	3.20 [-15.82, 22.22]
Franklin et al 2015	188.7	35.8	10	164.7	11.5	8	2.9%	24.00 [0.42, 47.58]
Gelecek et al 2012	198.25	43.4	24	225	51.83	21	2.5%	-26.75 [-54.91, 1.41]
Hagerman et al 2000	213.9	44.22	9	209.3	32.84	9	1.9%	4.60 [-31.39, 40.59]
Hallsworth et al 2011	193.1	65.6	11	177.6	34.7	8	1.4%	15.50 [-30.12, 61.12]
Heffernan et al 2013	245	10	11	208	11	10	4.6%	37.00 [27.98, 46.02]
Karelis et al 2016	185.3	34.7	10	173.7	30.9	10	2.4%	11.60 [-17.20, 40.40]
Kwon et al 2011	159.4	30	12	173	49.3	15	2.3%	-13.60 [-43.78, 16.58]
LeMura et al 2000	196.9	15.4	11	200.8	11.6	12	4.4%	-3.90 [-15.12, 7.32]
Libardi et al 2011	179.5	51.8	11	184.6	44.4	11	1.6%	-5.10 [-45.42, 35.22]
Mahdirejei et al 2014	171.1	37.91	9	160.87	28.33	9	2.3%	10.23 [-20.69, 41.15]
Manning et al 1991	198	44	16	205	60	6	1.1%	-7.00 [-59.63, 45.63]
Nybo et al 2010	204.6	11.6	8	158.3	11.6	11	4.5%	46.30 [35.74, 56.86]
Okamoto et al 2009b (Lower limb RT)	175	38	10	177	28	10	2.4%	-2.00 [-31.26, 27.26]
Prabhakaran et al 1999	164.5	8.9	12	177.6	11.2	12	4.7%	-13.10 [-21.19, -5.01]
Sillanpaa et al 2012	193.1	38.6	15	200.8	30.9	15	2.8%	-7.70 [-32.72, 17.32]
Song & Sohng 2012	148.7	26.2	20	162.1	26	20	3.8%	-13.40 [-29.58, 2.78]
Stensvold et al 2010	222.8	39.4	11	215.8	36.7	11	2.2%	7.00 [-24.82, 38.82]
Tanimoto et al 2009 (High intensity RT)	162.4	5.4	12	153.1	7.4	12	5.0%	9.30 [4.12, 14.48]
Venojarvi et al 2013	7.7	23.1	37	3.9	23.1	40	4.5%	3.80 [-6.53, 14.13]
Yoshizawa et al 2009	198.6	9.8	11	199.7	9.8	12	4.7%	-1.10 [-9.12, 6.92]
Subtotal (95% CI)			**442**			**440**	**100.0%**	**0.57 [-5.63, 6.77]**
Heterogeneity: Tau² = 194.72; Chi² = 190.82, df = 31 (P < 0.00001); I² = 84%								
Test for overall effect: Z = 0.18 (P = 0.86)								
1.6.3 Long Term								
Andersen et al 2016	189.1	23.2	9	200.8	23.2	8	12.9%	-11.70 [-33.80, 10.40]
Colado et al 2009	227.4	36.5	21	242.2	52.3	10	10.6%	-14.80 [-50.78, 21.18]
Olson 2006	173.7	29.9	15	169.9	29.9	15	13.0%	3.80 [-17.60, 25.20]
Vincent et al 2002 (High intensity RT)	157.8	18	15	198.9	49	10	11.3%	-41.10 [-72.81, -9.39]
Vincent et al 2006 (Normal weight)	166.02	11.6	10	196.9	15.4	10	14.1%	-30.88 [-42.83, -18.93]
Vincent et al 2006 (Overweight/Obese)	200.8	19.31	19	169.9	7.7	10	14.3%	30.90 [20.99, 40.81]
Wanderley et al 2013	221.7	27.3	11	230.3	35.3	19	12.8%	-8.60 [-31.23, 14.03]
Yavari et al 2012	176.1	49.3	15	180.1	44.5	15	11.0%	-4.00 [-37.61, 29.61]
Subtotal (95% CI)			**115**			**97**	**100.0%**	**-8.71 [-30.83, 13.40]**
Heterogeneity: Tau² = 863.32; Chi² = 71.91, df = 7 (P < 0.00001); I² = 90%								
Test for overall effect: Z = 0.77 (P = 0.44)								



Test for subgroup differences: Chi² = 1.35, df = 2 (P = 0.51), I² = 0%

Fig 20. Short-, medium-, long-term effects of resistance exercise training on total cholesterol levels as standardised mean difference and 95% CI.

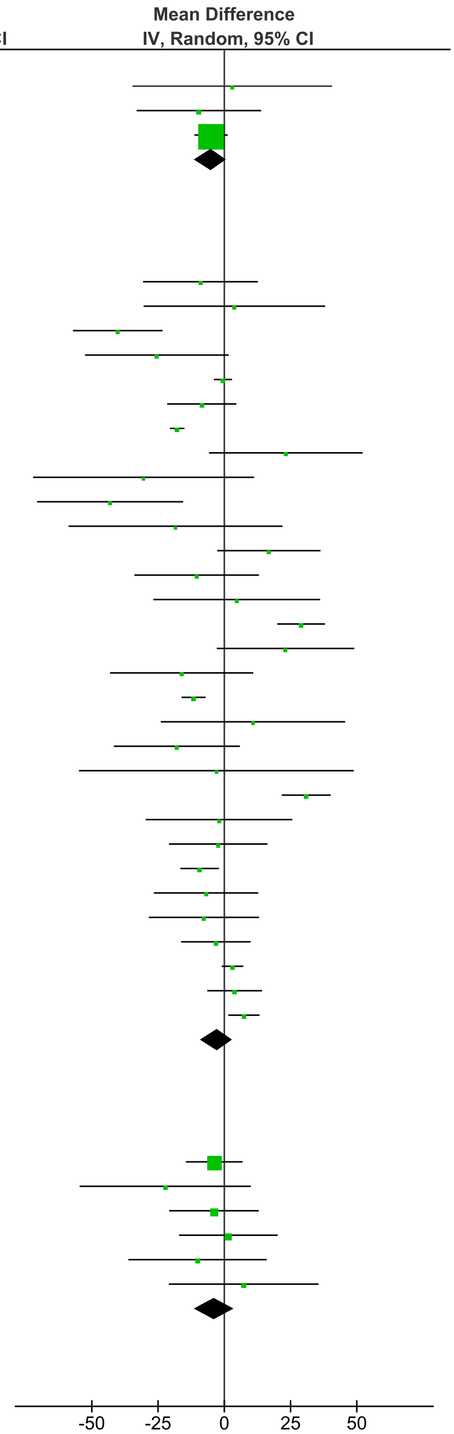
Study or Subgroup	Resistance Training Mean	Resistance Training SD	Resistance Training Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
1.7.1 Short Term								
Manning et al 1991	59	16	16	62	7.3	6	23.0%	-3.00 [-12.78, 6.78]
Vatani et al 2011 (High intensity RT)	59.1	5.1	10	52.5	8.3	10	35.4%	6.60 [0.56, 12.64]
Vona et al 2009	45	14	54	47	9	50	41.6%	-2.00 [-6.49, 2.49]
Subtotal (95% CI)			**80**			**66**	**100.0%**	**0.82 [-5.40, 7.03]**
Heterogeneity: Tau² = 18.93; Chi² = 5.60, df = 2 (P = 0.06); I² = 64%								
Test for overall effect: Z = 0.26 (P = 0.80)								
1.7.2 Medium Term								
Afshar et al 2010	32.24	10.12	7	31.71	12.47	7	1.9%	0.53 [-11.37, 12.43]
Almenning et al 2015	61.7	15.4	8	61.7	15.4	9	1.5%	0.00 [-14.67, 14.67]
Arora et al 2009	54	9.1	9	51	12.3	10	2.2%	3.00 [-6.67, 12.67]
Augusto Libardi et al 2012 (Female)	57.09	11.74	12	51.25	80.6	12	0.2%	5.84 [-40.24, 51.92]
Augusto Libardi et al 2012 (Male)	50.06	7.71	13	47.38	14.32	13	2.4%	2.68 [-6.16, 11.52]
Azarbayjani et al 2014	48.5	1.27	10	45.8	1.9	10	3.7%	2.70 [1.28, 4.12]
Boardley et al 2007	47.3	13.3	31	51.8	16.8	35	2.7%	-4.50 [-11.77, 2.77]
Castaneda et al 2002	48.3	2.3	29	47.9	2.7	31	3.7%	0.40 [-0.87, 1.67]
Christensen et al 2014	42.5	7.7	13	46.3	7.7	12	3.0%	-3.80 [-9.84, 2.24]
Conceicao et al 2013	57.64	12.7	10	52	7.24	10	2.3%	5.64 [-3.42, 14.70]
Deibert et al 2011	55.5	16.1	15	60	9.4	10	2.2%	-4.50 [-14.52, 5.52]
DeVallance et al 2016 (Healthy)	69.5	3.9	16	46.3	3.9	12	3.5%	23.20 [20.28, 26.12]
DeVallance et al 2016 (Metabolic syndrome)	46.3	3.9	13	42.5	3.9	16	3.5%	3.80 [0.95, 6.65]
Elliott et al 2002	78.8	15.4	8	61.4	18.6	7	1.2%	17.40 [-0.03, 34.83]
Fahlman et al 2002	57.4	2	15	38.6	3.6	15	3.6%	18.80 [16.72, 20.88]
Fenkci et al 2006	52.1	9.48	17	50.1	14.5	17	2.5%	2.00 [-6.24, 10.24]
Franklin et al 2015	56.7	12.6	10	57.7	11.5	8	2.0%	-1.00 [-12.16, 10.16]
Gelecek et al 2012	52.08	10.39	24	57.28	9.08	21	3.0%	-5.20 [-10.89, 0.49]
Hagerman et al 2000	46.9	7.62	9	40.7	9.31	9	2.6%	6.20 [-1.66, 14.06]
Heffernan et al 2013	61	4	11	53	4	10	3.4%	8.00 [4.57, 11.43]
Karelis et al 2016	61.8	10.3	10	50.2	15.4	10	1.9%	11.60 [0.12, 23.08]
Kwon et al 2011	44.1	6.3	12	45.5	13.1	15	2.7%	-1.40 [-8.93, 6.13]
LeMura et al 2000	57.9	3.9	11	57.9	3.9	12	3.5%	0.00 [-3.19, 3.19]
Levinger et al 2007 (High metabolic risk)	57.9	15.4	15	46.3	15.4	14	2.0%	11.60 [0.38, 22.82]
Levinger et al 2007 (Low metabolic risk)	69.5	23.2	10	57.9	19.3	10	1.1%	11.60 [-7.10, 30.30]
Libardi et al 2011	51.4	7.3	11	47.1	14.3	13	2.4%	4.30 [-4.59, 13.19]
Mahdirejei et al 2014	42.8	8.87	9	41.93	8.21	9	2.6%	0.87 [-7.03, 8.77]
Manning et al 1991	55	16	16	61	12	6	1.8%	-6.00 [-18.40, 6.40]
Nybo et al 2010	46.3	3.9	8	54.1	3.9	11	3.4%	-7.80 [-11.35, -4.25]
Okamoto et al 2009b (Lower limb RT)	59	10	10	62	14	10	2.1%	-3.00 [-13.66, 7.66]
Plotnikoff et al 2010	47.9	15.4	27	42.5	11.6	21	2.6%	5.40 [-2.24, 13.04]
Prabhakaran et al 1999	49.03	3.9	12	51.4	3.1	12	3.5%	-2.37 [-5.19, 0.45]
Sigal et al 2009	42.9	15.4	64	41.7	15.4	63	3.1%	1.20 [-4.16, 6.56]
Sillanpaa et al 2012	34.7	11.6	15	34.7	7.7	15	2.8%	0.00 [-7.05, 7.05]
Song & Sohng 2012	41.5	10.1	20	42.7	15.4	20	2.5%	-1.20 [-9.27, 6.87]
Stensvold et al 2010	222.8	39.4	11	215.8	36.7	11	0.5%	7.00 [-24.82, 38.82]
Tanimoto et al 2009 (High intensity RT)	63.1	4.1	12	56.3	3.7	12	3.5%	6.80 [3.68, 9.92]
Venojarvi et al 2013	3.9	0.003	37	3.9	0.003	40	3.7%	0.00 [-0.00, 0.00]
Yoshizawa et al 2009	53.2	3.1	11	69.4	6	12	3.4%	-16.20 [-20.06, -12.34]
Subtotal (95% CI)			**601**			**590**	**100.0%**	**2.23 [-0.06, 4.51]**
Heterogeneity: Tau² = 36.32; Chi² = 734.44, df = 38 (P < 0.00001); I² = 95%								
Test for overall effect: Z = 1.91 (P = 0.06)								
1.7.3 Long Term								
Andersen et al 2016	54.1	11.6	9	61.8	10.9	8	8.0%	-7.70 [-18.40, 3.00]
Colado et al 2009	72	9.7	21	67.7	14.9	10	8.7%	4.30 [-5.82, 14.42]
Olson 2006	50.2	15	15	50.2	15	15	8.0%	0.00 [-10.74, 10.74]
Sigal et al 2009	42.9	15.4	64	40.9	15.4	63	18.6%	2.00 [-3.36, 7.36]
Vincent et al 2002 (High intensity RT)	63.4	12	15	52.4	6	10	13.9%	11.00 [3.88, 18.12]
Vincent et al 2006 (Normal weight)	61.8	11.6	10	54.1	3.9	10	12.9%	7.70 [0.11, 15.29]
Vincent et al 2006 (Overweight/Obese)	50.2	11.6	19	54.1	15.4	10	7.8%	-3.90 [-14.78, 6.98]
Wanderley et al 2013	59.1	20.1	11	57.3	17	19	5.1%	1.80 [-12.33, 15.93]
Yavari et al 2012	45.2	8.7	15	43.1	8	15	16.8%	2.10 [-3.88, 8.08]
Subtotal (95% CI)			**179**			**160**	**100.0%**	**2.79 [-0.69, 6.28]**
Heterogeneity: Tau² = 9.45; Chi² = 12.32, df = 8 (P = 0.14); I² = 35%								
Test for overall effect: Z = 1.57 (P = 0.12)								



Test for subgroup differences: Chi² = 0.30, df = 2 (P = 0.86), I² = 0%

Fig 21. Short-, medium-, long-term effects of resistance exercise training on high density lipoprotein cholesterol levels as standardised mean difference and 95% CI.

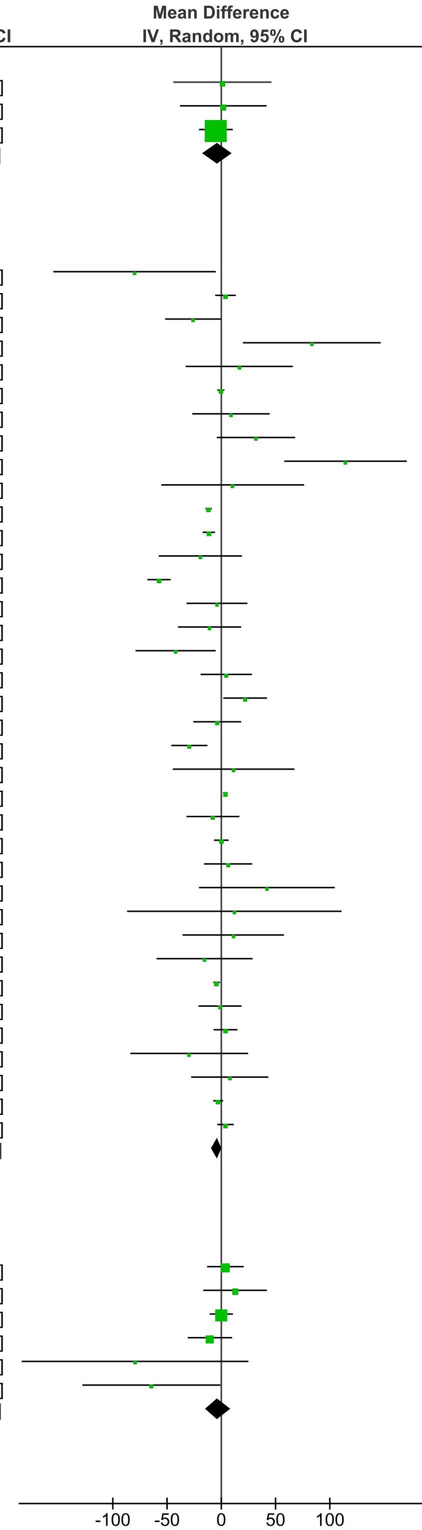
Study or Subgroup	Resistance Training Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
1.8.1 Short Term								
Manning et al 1991	119	36	16	116	41.6	6	2.5%	3.00 [-34.67, 40.67]
Vatani et al 2011 (High intensity RT)	95.1	22.7	10	104.7	30.4	10	6.5%	-9.60 [-33.12, 13.92]
Vona et al 2009	91	20	54	96	12	50	91.0%	-5.00 [-11.29, 1.29]
Subtotal (95% CI)			**80**			**66**	**100.0%**	**-5.10 [-11.09, 0.90]**
Heterogeneity: Tau² = 0.00; Chi² = 0.32, df = 2 (P = 0.85); I² = 0%								
Test for overall effect: Z = 1.67 (P = 0.10)								
1.8.2 Medium Term								
Afshar et al 2010	51.14	26.32	7	60.14	12.77	7	3.0%	-9.00 [-30.67, 12.67]
Almenning et al 2015	100.4	23.2	8	96.6	46.3	9	1.9%	3.80 [-30.46, 38.06]
Augusto Libardi et al 2012 (Female)	85.86	24.59	12	126.08	16.99	12	3.6%	-40.22 [-57.13, -23.31]
Augusto Libardi et al 2012 (Male)	88.18	32.95	13	113.62	37.48	13	2.4%	-25.44 [-52.57, 1.69]
Azarbayjani et al 2014	93.9	3.18	10	94.4	4.52	10	5.0%	-0.50 [-3.93, 2.93]
Boardley et al 2007	103.2	21.1	31	111.7	32.4	35	4.0%	-8.50 [-21.55, 4.55]
Castaneda et al 2002	104.2	5.02	29	122	5.8	31	5.0%	-17.80 [-20.54, -15.06]
Christensen et al 2014	158.3	42.5	13	135.1	30.9	12	2.3%	23.20 [-5.77, 52.17]
Elliott et al 2002	127.03	33.6	8	157.5	46.7	7	1.4%	-30.47 [-72.17, 11.23]
Fahlman et al 2002	89	43.4	15	132.1	32.9	15	2.4%	-43.10 [-70.66, -15.54]
Fenkci et al 2006	119	36	17	137.4	76.9	17	1.5%	-18.40 [-58.76, 21.96]
Franklin et al 2015	109.3	25.9	10	92.5	16	8	3.3%	16.80 [-2.71, 36.31]
Gelecek et al 2012	126.04	32.09	24	136.47	46.05	21	2.8%	-10.43 [-33.94, 13.08]
Hagerman et al 2000	144.4	35.56	9	139.7	32.51	9	2.1%	4.70 [-26.78, 36.18]
Heffernan et al 2013	151	10	11	122	11	10	4.5%	29.00 [19.98, 38.02]
Karelis et al 2016	115.8	23.2	10	92.7	34.8	10	2.6%	23.10 [-2.82, 49.02]
Kwon et al 2011	87.9	28.8	13	104	43.5	15	2.5%	-16.10 [-43.11, 10.91]
LeMura et al 2000	115.8	7.7	11	127.4	0.001	12	4.9%	-11.60 [-16.15, -7.05]
Libardi et al 2011	124.3	47.7	11	113.5	37.5	13	1.8%	10.80 [-23.99, 45.59]
Mahdirejei et al 2014	88.6	28.72	9	106.5	22.36	9	2.8%	-17.90 [-41.68, 5.88]
Manning et al 1991	119	40	16	122	60	6	1.0%	-3.00 [-54.86, 48.86]
Nybo et al 2010	135.1	11.6	8	104.2	7.7	11	4.5%	30.90 [21.66, 40.14]
Okamoto et al 2009b (Lower limb RT)	105	37	10	107	25	10	2.4%	-2.00 [-29.68, 25.68]
Plotnikoff et al 2010	95.8	34.7	27	98.1	30.9	21	3.4%	-2.30 [-20.90, 16.30]
Prabhakaran et al 1999	99.2	8.1	12	108.5	10.04	12	4.7%	-9.30 [-16.60, -2.00]
Sigal et al 2009	113.1	58.3	64	120	54.9	63	3.2%	-6.90 [-26.59, 12.79]
Sillanpaa et al 2012	139	27.03	15	146.7	30.9	15	3.1%	-7.70 [-28.48, 13.08]
Song & Sohng 2012	78.1	21.1	20	81.3	21.2	20	4.0%	-3.20 [-16.31, 9.91]
Tanimoto et al 2009 (High intensity RT)	88	5.1	12	84.9	5.1	12	4.9%	3.10 [-0.98, 7.18]
Venojarvi et al 2013	7.8	23.1	37	3.9	23.1	40	4.4%	3.90 [-6.43, 14.23]
Yoshizawa et al 2009	122	8.1	11	114.6	6.1	12	4.8%	7.40 [1.50, 13.30]
Subtotal (95% CI)			**503**			**497**	**100.0%**	**-2.86 [-8.77, 3.05]**
Heterogeneity: Tau² = 180.31; Chi² = 292.46, df = 30 (P < 0.00001); I² = 90%								
Test for overall effect: Z = 0.95 (P = 0.34)								
1.8.3 Long Term								
Andersen et al 2016	58	11.6	9	61.8	10.9	8	46.5%	-3.80 [-14.50, 6.90]
Colado et al 2009	136.9	31.7	21	159.2	47.3	10	5.1%	-22.30 [-54.60, 10.00]
Olson 2006	104.2	29.9	15	108.1	15	15	18.6%	-3.90 [-20.83, 13.03]
Sigal et al 2009	116.22	55.2	64	114.7	51.7	63	15.4%	1.52 [-17.08, 20.12]
Wanderley et al 2013	162.5	29.2	11	172.6	43.6	19	7.8%	-10.10 [-36.22, 16.02]
Yavari et al 2012	100.6	45.2	15	93.3	32.7	15	6.7%	7.30 [-20.93, 35.53]
Subtotal (95% CI)			**135**			**130**	**100.0%**	**-3.69 [-10.99, 3.60]**
Heterogeneity: Tau² = 0.00; Chi² = 2.39, df = 5 (P = 0.79); I² = 0%								
Test for overall effect: Z = 0.99 (P = 0.32)								



Test for subgroup differences: Chi² = 0.28, df = 2 (P = 0.87), I² = 0%

Fig 22. Short-, medium-, long-term effects of resistance exercise training on low density lipoprotein cholesterol levels as standardised mean difference and 95% CI.

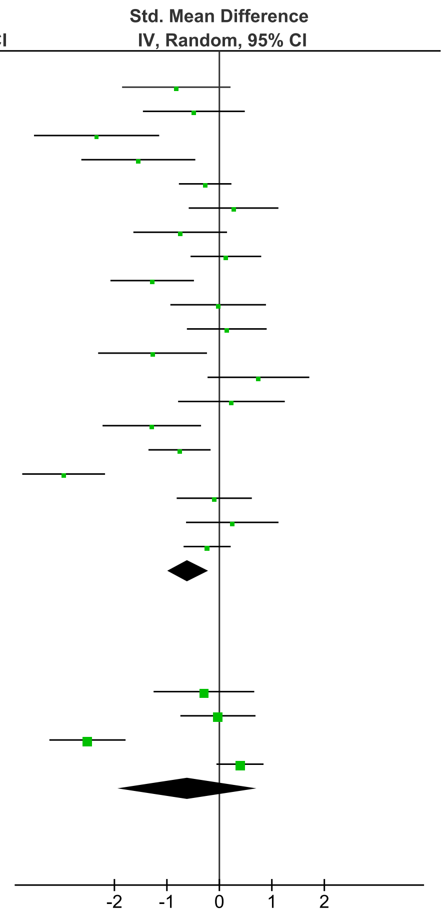
Study or Subgroup	Resistance Training Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
1.9.1 Short Term								
Manning et al 1991	105	28	16	104	53.9	6	9.3%	1.00 [-44.26, 46.26]
Vatani et al 2011 (High intensity RT)	98.5	38.6	10	96.7	51.6	10	12.0%	1.80 [-38.14, 41.74]
Vona et al 2009	140	44	54	145	37	50	78.7%	-5.00 [-20.59, 10.59]
Subtotal (95% CI)			**80**			**66**	**100.0%**	**-3.63 [-17.45, 10.20]**
Heterogeneity: Tau² = 0.00; Chi² = 0.14, df = 2 (P = 0.93); I² = 0%								
Test for overall effect: Z = 0.51 (P = 0.61)								
1.9.2 Medium Term								
Afshar et al 2010	145.71	61.86	7	225.71	79.97	7	0.4%	-80.00 [-154.90, -5.10]
Almenning et al 2015	30.9	11.6	8	27.03	7.7	9	5.0%	3.87 [-5.61, 13.35]
Arora et al 2009	139	18.9	9	165	36.5	10	2.2%	-26.00 [-51.77, -0.23]
Augusto Libardi et al 2012 (Female)	221.77	91.33	12	138.33	65.37	12	0.5%	83.44 [19.89, 146.99]
Augusto Libardi et al 2012 (Male)	150.75	41.1	13	134.15	80.97	13	0.8%	16.60 [-32.76, 65.96]
Azarbayjani et al 2014	92.6	2.68	10	93	4.57	10	6.0%	-0.40 [-3.68, 2.88]
Boardley et al 2007	143.7	73.1	31	134.8	74.5	35	1.4%	8.90 [-26.76, 44.56]
Christensen et al 2014	83	65.3	13	51	11.6	12	1.4%	32.00 [-4.10, 68.10]
Conceicao et al 2013	232.31	78	10	117.8	47.13	10	0.6%	114.51 [58.03, 170.99]
Deibert et al 2011	143.8	104.7	13	133.3	50.7	9	0.5%	10.50 [-55.35, 76.35]
DeVallance et al 2016 (Healthy)	27	3.9	16	38.7	3.9	12	6.0%	-11.70 [-14.62, -8.78]
DeVallance et al 2016 (Metabolic syndrome)	58	7.8	13	69.5	7.8	16	5.7%	-11.50 [-17.21, -5.79]
Elliott et al 2002	52.9	18.1	8	72.2	49	7	1.2%	-19.30 [-57.70, 19.10]
Fahlman et al 2002	84.6	12.9	15	142	16.8	15	4.7%	-57.40 [-68.12, -46.68]
Fenkci et al 2006	102.4	40.3	17	106.4	43.2	17	2.0%	-4.00 [-32.08, 24.08]
Gelecek et al 2012	149.6	53.64	24	160.42	46.2	21	1.9%	-10.82 [-39.99, 18.35]
Hagerman et al 2000	99.8	32.14	9	141.9	46.54	9	1.3%	-42.10 [-79.05, -5.15]
Hallsworth et al 2011	62.5	21.2	11	57.9	29	8	2.5%	4.60 [-19.08, 28.28]
Heffernan et al 2013	146	23	11	124	24	10	2.9%	22.00 [1.85, 42.15]
Karelis et al 2016	50.2	27	10	54	23.2	10	2.7%	-3.80 [-25.86, 18.26]
Kemmler et al 2016	-5.5	35.4	38	23.9	39.6	40	3.5%	-29.40 [-46.05, -12.75]
Kwon et al 2011	151.3	81.5	12	139.9	63	15	0.7%	11.40 [-44.66, 67.46]
LeMura et al 2000	54	0.01	11	50.2	3.9	12	6.1%	3.80 [1.59, 6.01]
Levinger et al 2007 (High metabolic risk)	54.1	27	15	61.8	38.6	14	2.4%	-7.70 [-32.10, 16.70]
Levinger et al 2007 (Low metabolic risk)	34.7	7.7	10	34.7	7.7	10	5.5%	0.00 [-6.75, 6.75]
Libardi et al 2011	64.5	19.31	11	58.3	35.1	13	2.6%	6.20 [-16.03, 28.43]
Mahdirejei et al 2014	174.9	84.6	9	132.87	45	9	0.5%	42.03 [-20.57, 104.63]
Manning et al 1991	126	48	16	114	120	6	0.2%	12.00 [-86.86, 110.86]
Okamoto et al 2009b (Lower limb RT)	97	47	10	86	59	10	0.9%	11.00 [-35.75, 57.75]
Plotnikoff et al 2010	75.3	42.5	27	90.73	96.5	21	1.0%	-15.43 [-59.71, 28.85]
Prabhakaran et al 1999	34.7	3.9	12	39	3.9	12	6.0%	-4.30 [-7.42, -1.18]
Sigal et al 2009	69.1	58.7	64	70.3	55.2	63	3.0%	-1.20 [-21.01, 18.61]
Sillanpaa et al 2012	42.5	15.4	15	38.6	15.4	15	4.6%	3.90 [-7.12, 14.92]
Song & Sohng 2012	118.3	63.3	20	147.9	106.5	20	0.7%	-29.60 [-83.90, 24.70]
Stensvold et al 2010	73.4	46.3	11	65.6	38.6	11	1.4%	7.80 [-27.82, 43.42]
Tanimoto et al 2009 (High intensity RT)	56.9	6.3	12	59.8	5.1	12	5.8%	-2.90 [-7.49, 1.69]
Venojarvi et al 2013	0.003	7.8	37	-3.9	23.1	40	5.3%	3.90 [-3.68, 11.49]
Subtotal (95% CI)			**590**			**575**	**100.0%**	**-3.99 [-8.78, 0.80]**
Heterogeneity: Tau² = 96.94; Chi² = 250.54, df = 36 (P < 0.00001); I² = 86%								
Test for overall effect: Z = 1.63 (P = 0.10)								
1.9.3 Long Term								
Andersen et al 2016	46.3	11.6	9	42.5	21.8	8	25.5%	3.80 [-13.10, 20.70]
Colado et al 2009	96.8	42.9	21	84.1	36.9	10	12.8%	12.70 [-16.62, 42.02]
Olson 2006	38.6	15	15	38.6	15	15	36.2%	0.00 [-10.74, 10.74]
Sigal et al 2009	62.5	56	64	73	61.4	63	20.8%	-10.50 [-30.95, 9.95]
Wanderley et al 2013	77.4	28.8	11	156.9	229.3	19	1.3%	-79.50 [-184.00, 25.00]
Yavari et al 2012	156.5	78.9	15	220.9	97.9	15	3.4%	-64.40 [-128.03, -0.77]
Subtotal (95% CI)			**135**			**130**	**100.0%**	**-2.82 [-14.98, 9.33]**
Heterogeneity: Tau² = 76.42; Chi² = 7.99, df = 5 (P = 0.16); I² = 37%								
Test for overall effect: Z = 0.46 (P = 0.65)								



Test for subgroup differences: Chi² = 0.03, df = 2 (P = 0.98), I² = 0%

Fig 23. Short-, medium-, long-term effects of resistance exercise training on triglyceride levels as standardised mean difference and 95% CI.

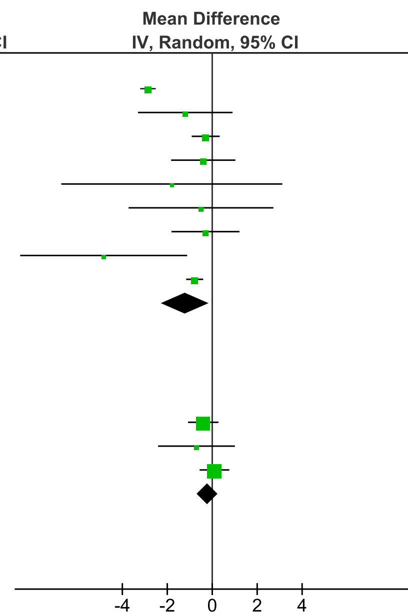
Study or Subgroup	Resistance Training Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.10.1 Medium Term								
Ahmadizad et al 2014 (Non-periodised RT)	76.5	7.1	8	85.7	13.2	8	4.5%	-0.82 [-1.85, 0.21]
Almenning et al 2015	13.6	6.3	8	18.3	11.1	9	4.7%	-0.49 [-1.46, 0.48]
Azarbayjani et al 2014	5.67	0.19	10	6.79	0.62	10	4.0%	-2.34 [-3.53, -1.15]
Baldi & Snowling 2003	21.1	4.1	9	30.9	7.5	9	4.3%	-1.54 [-2.63, -0.46]
Brooks et al 2007	14.63	9.75	31	18.53	17.6	31	6.0%	-0.27 [-0.77, 0.23]
Deibert et al 2011	11.7	6	13	10.1	5.2	9	5.0%	0.27 [-0.58, 1.12]
Dunstan et al 1998	8.7	5.8	11	13.1	5.5	10	4.9%	-0.75 [-1.64, 0.15]
Fenkci et al 2006	12.6	5.7	17	11.9	5.3	17	5.5%	0.12 [-0.55, 0.80]
Gordon et al 2006	18.4	1.95	15	23.41	5.02	15	5.2%	-1.28 [-2.08, -0.48]
Hallsworth et al 2011	2.6	1.84	11	2.64	1.4	8	4.8%	-0.02 [-0.93, 0.89]
Kwon et al 2011	4.3	3.7	12	3.8	3.2	15	5.3%	0.14 [-0.62, 0.90]
Mahdirejei et al 2014	8.12	3.78	9	20.62	12.67	9	4.5%	-1.27 [-2.31, -0.24]
Malin et al 2013 (High body fat)	29.5	5.5	12	24.8	6.9	7	4.7%	0.74 [-0.22, 1.71]
Marcus et al 2009	10.6	10.7	10	8.3	6.6	6	4.5%	0.23 [-0.79, 1.25]
Nikseresht et al 2014	3.66	0.92	12	6.2	2.64	10	4.7%	-1.29 [-2.23, -0.35]
Plotnikoff et al 2010	12.6	6.5	27	19.14	10.5	21	5.8%	-0.76 [-1.35, -0.17]
Schmitz et al 2002	-0.29	0.35	27	0.81	0.38	27	5.2%	-2.97 [-3.76, -2.18]
Sillanpaa et al 2012	3.9	1.5	15	4.1	2.4	15	5.4%	-0.10 [-0.81, 0.62]
Stensvold et al 2012	16.28	6.2	10	15.03	3	10	4.9%	0.25 [-0.63, 1.13]
Venojarvi et al 2013	-0.1	0.9	37	0.1	0.8	40	6.1%	-0.23 [-0.68, 0.22]
Subtotal (95% CI)			**304**			**286**	**100.0%**	**-0.59 [-0.97, -0.21]**
Heterogeneity: Tau² = 0.55; Chi² = 84.86, df = 19 (P < 0.00001); I² = 78%								
Test for overall effect: Z = 3.07 (P = 0.002)								
1.10.2 Long Term								
Andersen et al 2016	35	12	9	40	19.8	8	23.7%	-0.29 [-1.25, 0.66]
Olson 2006	5.8	2.7	15	5.9	4.3	15	25.1%	-0.03 [-0.74, 0.69]
Schmitz et al 2002	0.05	0.42	27	1.16	0.45	27	25.0%	-2.51 [-3.24, -1.79]
Schmitz et al 2005	8.21	0.69	38	7.94	0.67	40	26.2%	0.39 [-0.06, 0.84]
Subtotal (95% CI)			**89**			**90**	**100.0%**	**-0.60 [-1.93, 0.72]**
Heterogeneity: Tau² = 1.69; Chi² = 45.43, df = 3 (P < 0.00001); I² = 93%								
Test for overall effect: Z = 0.89 (P = 0.37)								



Test for subgroup differences: Chi² = 0.00, df = 1 (P = 0.99), I² = 0%

Fig 24. Medium- and long-term effects of resistance exercise training on fasted insulin levels as standardised mean difference and 95% CI.

Study or Subgroup	Resistance Training Mean	Resistance Training SD	Resistance Training Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
1.11.1 Medium Term								
Ahmadizad et al 2014 (Non-periodised RT)	17.34	0.03	8	20.2	0.5	8	16.4%	-2.86 [-3.21, -2.51]
Almenning et al 2015	3.1	1.5	8	4.3	2.8	9	10.1%	-1.20 [-3.30, 0.90]
Azarbayjani et al 2014	1.14	0.98	10	1.43	0.22	10	15.8%	-0.29 [-0.91, 0.33]
Deibert et al 2011	1.9	2.2	13	2.3	1.2	9	12.9%	-0.40 [-1.83, 1.03]
Gordon et al 2006	5.3	6.3	15	7.1	7.4	15	3.7%	-1.80 [-6.72, 3.12]
Hallsworth et al 2011	4.6	4.6	11	5.1	2.5	8	6.6%	-0.50 [-3.72, 2.72]
Karelis et al 2016	4.4	1.4	10	4.7	2	10	12.5%	-0.30 [-1.81, 1.21]
Mahdirejei et al 2014	3.32	1.87	9	8.15	5.37	9	5.5%	-4.83 [-8.54, -1.12]
Nikseresht et al 2014	0.84	0.27	12	1.62	0.56	10	16.4%	-0.78 [-1.16, -0.40]
Subtotal (95% CI)			**96**			**88**	**100.0%**	**-1.22 [-2.29, -0.15]**
Heterogeneity: Tau² = 1.77; Chi² = 94.62, df = 8 (P < 0.00001); I² = 92%								
Test for overall effect: Z = 2.24 (P = 0.02)								
1.11.2 Long Term								
Andersen et al 2016	1.3	0.6	9	1.7	0.8	8	45.1%	-0.40 [-1.08, 0.28]
Fatouros et al 2005 (High intensity 80-85% 1RM)	3.1	1.8	14	3.8	2.3	10	7.1%	-0.70 [-2.41, 1.01]
Olson 2006	5.9	1.1	15	5.8	0.7	15	47.8%	0.10 [-0.56, 0.76]
Subtotal (95% CI)			**38**			**33**	**100.0%**	**-0.18 [-0.64, 0.27]**
Heterogeneity: Tau² = 0.00; Chi² = 1.45, df = 2 (P = 0.48); I² = 0%								
Test for overall effect: Z = 0.78 (P = 0.43)								

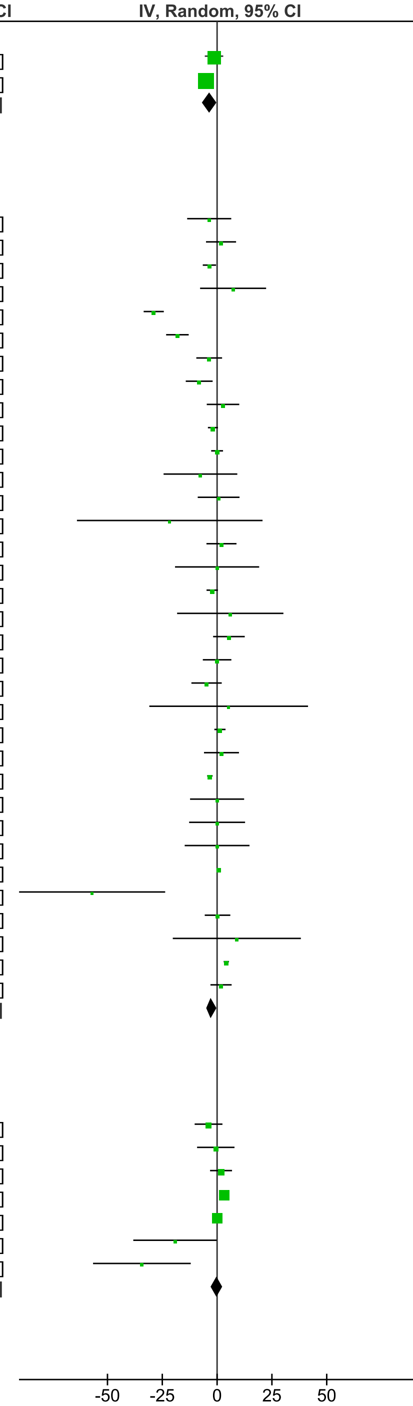


Test for subgroup differences: Chi² = 3.07, df = 1 (P = 0.08), I² = 67.5%

Fig 25. Medium- and long-term effects of resistance exercise training on insulin resistance (HOMA-IR) as standardised mean difference and 95% CI.

Study or Subgroup	Resistance Training Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
1.12.1 Short Term								
Hedayati et al 2012 (80% 1RM)	83.1	4.9	10	84.5	4.2	8	44.6%	-1.40 [-5.61, 2.81]
Vona et al 2009	85	8.2	54	90	9.9	50	55.4%	-5.00 [-8.51, -1.49]
Subtotal (95% CI)			**64**			**58**	**100.0%**	**-3.39 [-6.90, 0.11]**
Heterogeneity: Tau² = 2.57; Chi² = 1.66, df = 1 (P = 0.20); I² = 40%								
Test for overall effect: Z = 1.90 (P = 0.06)								
1.12.2 Medium Term								
Ahmadizad et al 2014 (Non-periodised RT)	91.9	1.8	8	95.5	14.4	8	2.3%	-3.60 [-13.66, 6.46]
Almenning et al 2015	91.9	7.2	8	90.1	7.2	9	3.3%	1.80 [-5.06, 8.66]
Azarbayjani et al 2014	45.3	3.2	10	48.8	3.7	10	4.6%	-3.50 [-6.53, -0.47]
Baldi & Snowling 2003	205.5	14.4	9	198.2	18	9	1.4%	7.30 [-7.76, 22.36]
Brooks et al 2007	142.3	7.2	31	171.2	10.9	31	4.1%	-28.90 [-33.50, -24.30]
Castaneda et al 2002	142.3	7.2	29	160.4	12.6	31	3.9%	-18.10 [-23.25, -12.95]
Christensen et al 2014	91.9	5.4	13	95.5	9	12	3.7%	-3.60 [-9.48, 2.28]
Conceicao et al 2013	84.94	6.33	10	93.1	7.6	10	3.6%	-8.16 [-14.29, -2.03]
Deibert et al 2011	93	8.3	13	90.3	9	9	3.1%	2.70 [-4.71, 10.11]
DeVallance et al 2016 (Healthy)	90.1	1.9	16	92	3.7	12	4.9%	-1.90 [-4.19, 0.39]
DeVallance et al 2016 (Metabolic syndrome)	97.3	3.7	13	97.3	3.7	16	4.7%	0.00 [-2.71, 2.71]
Dunstan et al 1998	169.4	14.4	11	177	23.4	10	1.2%	-7.60 [-24.42, 9.22]
Franklin et al 2015	87.5	12	10	86.8	8.6	8	2.5%	0.70 [-8.83, 10.23]
Hallsworth et al 2011	93.7	16.2	11	115.3	59.5	8	0.2%	-21.60 [-63.93, 20.73]
Heffernan et al 2013	97	8	11	95	8	10	3.3%	2.00 [-4.85, 8.85]
Karelis et al 2016	93.7	18	10	93.7	25.2	10	1.0%	0.00 [-19.19, 19.19]
Kemmler et al 2016	-2.41	6.33	38	-0.19	5.27	40	4.8%	-2.22 [-4.81, 0.37]
Ku et al 2010	127	39	13	121	24	16	0.6%	6.00 [-18.24, 30.24]
Levinger et al 2007 (High metabolic risk)	104.5	10.8	15	99.1	9	14	3.2%	5.40 [-1.82, 12.62]
Levinger et al 2007 (Low metabolic risk)	90.1	5.4	10	90.1	9	10	3.4%	0.00 [-6.51, 6.51]
Libardi et al 2011	93	5.2	11	97.8	11.4	13	3.3%	-4.80 [-11.72, 2.12]
Mahdirejei et al 2014	164.4	48.26	9	159.12	27.22	9	0.3%	5.28 [-30.92, 41.48]
Malin et al 2013 (High body fat)	84.5	2.8	12	83.2	2.7	7	4.8%	1.30 [-1.25, 3.85]
Marcus et al 2009	98.4	7.5	10	96.4	8.1	6	2.9%	2.00 [-5.98, 9.98]
Nikseresht et al 2014	101.4	1.3	12	104.7	1.6	10	5.1%	-3.30 [-4.53, -2.07]
Nybo et al 2010	102.8	9	8	102.8	18	11	1.8%	0.00 [-12.33, 12.33]
Okamoto et al 2009b (Lower limb RT)	87	18	10	87	10	10	1.8%	0.00 [-12.76, 12.76]
Plotnikoff et al 2010	127.9	30.6	27	127.9	21.6	21	1.4%	0.00 [-14.78, 14.78]
Schmitz et al 2002	1.92	1.27	27	1.21	1.36	27	5.1%	0.71 [0.01, 1.41]
Shenoy et al 2009	104	12.2	9	161	52.2	10	0.4%	-57.00 [-90.32, -23.68]
Sillanpaa et al 2012	101.1	9	15	100.9	7.2	15	3.7%	0.20 [-5.63, 6.03]
Stensvold et al 2010	118.9	27	11	109.9	41.4	11	0.5%	9.00 [-20.21, 38.21]
Tanimoto et al 2009 (High intensity RT)	89	1.8	12	84.8	1.1	12	5.1%	4.20 [3.01, 5.39]
Venojarvi et al 2013	-1.8	10.8	37	-3.6	10.81	40	4.0%	1.80 [-3.03, 6.63]
Subtotal (95% CI)			**499**			**485**	**100.0%**	**-2.39 [-4.47, -0.31]**
Heterogeneity: Tau² = 21.89; Chi² = 318.33, df = 33 (P < 0.00001); I² = 90%								
Test for overall effect: Z = 2.25 (P = 0.02)								
1.12.3 Long Term								
Colado et al 2009	97	7.8	15	100.9	8	10	11.7%	-3.90 [-10.24, 2.44]
Fatouros et al 2005 (High intensity 80-85% 1RM)	106.1	8.2	14	106.7	11.9	10	7.8%	-0.60 [-9.14, 7.94]
Olson 2006	86.5	7	15	84.7	7	15	15.4%	1.80 [-3.21, 6.81]
Schmitz et al 2002	3.55	1.37	27	0.36	1.5	27	30.9%	3.19 [2.42, 3.96]
Schmitz et al 2005	88.49	1.88	38	88.35	1.85	40	30.8%	0.14 [-0.69, 0.97]
Wanderley et al 2013	88.8	21.6	11	108	31.4	19	1.9%	-19.20 [-38.23, -0.17]
Yavari et al 2012	122.7	23.4	15	157	37.3	15	1.4%	-34.30 [-56.58, -12.02]
Subtotal (95% CI)			**135**			**136**	**100.0%**	**-0.07 [-2.80, 2.67]**
Heterogeneity: Tau² = 6.16; Chi² = 46.09, df = 6 (P < 0.00001); I² = 87%								
Test for overall effect: Z = 0.05 (P = 0.96)								

Mean Difference
IV, Random, 95% CI



Test for subgroup differences: Chi² = 2.63, df = 2 (P = 0.27), I² = 24.1%

Fig 26. Short-, medium-, long-term effects of resistance exercise training on fasted glucose levels as standardised mean difference and 95% CI.

	Resistance Training			Control				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
1.13.1 Short Term								
Borges & Carvalho 2014	2.8	2.8	31	4.1	8.1	31	67.5%	-0.21 [-0.71, 0.29]
Vatani et al 2011 (High intensity RT) *	0.48	0.15	10	0.61	0.13	10	32.5%	-0.89 [-1.82, 0.04]
Subtotal (95% CI)			**41**			**41**	**100.0%**	**-0.43 [-1.05, 0.19]**
Heterogeneity: Tau² = 0.08; Chi² = 1.58, df = 1 (P = 0.21); I² = 37%								
Test for overall effect: Z = 1.36 (P = 0.17)								
1.13.2 Medium Term								
Afshar et al 2010 *	2.27	1.79	7	4.14	3.87	7	6.9%	-0.58 [-1.66, 0.50]
Almenning et al 2015 *	1.8	2.7	8	1.6	2.4	7	7.2%	0.07 [-0.94, 1.09]
Brooks et al 2007	2.8	2.8	31	4.1	8.1	31	10.2%	-0.21 [-0.71, 0.29]
Franklin et al 2015	5	3.2	10	2.7	3	8	7.5%	0.70 [-0.26, 1.67]
Greenwood et al 2015 *	4.1	7.2	13	6.8	8.5	20	9.0%	-0.33 [-1.03, 0.37]
Heffernan et al 2013	3	2.8	11	8.4	3	10	7.0%	-1.79 [-2.84, -0.74]
Libardi et al 2011 *	1.3	1.2	12	0.8	1.1	13	8.5%	0.42 [-0.37, 1.22]
Nikseresht et al 2014 *	3.17	0.46	12	3.25	0.56	13	8.5%	-0.15 [-0.94, 0.64]
Plotnikoff et al 2010 *	4.5	4.1	27	4.2	4.8	21	9.8%	0.07 [-0.50, 0.64]
Rodriguez-Miguelez et al 2014	0.64	0.07	16	0.9	0.08	10	5.9%	-3.41 [-4.69, -2.13]
Sillanpaa et al 2012 *	1.64	2.41	15	1.03	1.2	15	8.9%	0.31 [-0.41, 1.03]
Venojarvi et al 2013 *	0.3	2.4	37	-0.1	2	40	10.5%	0.18 [-0.27, 0.63]
Subtotal (95% CI)			**199**			**195**	**100.0%**	**-0.28 [-0.72, 0.15]**
Heterogeneity: Tau² = 0.42; Chi² = 44.57, df = 11 (P < 0.00001); I² = 75%								
Test for overall effect: Z = 1.27 (P = 0.20)								

Test for subgroup differences: Chi² = 0.15, df = 1 (P = 0.70), I² = 0%

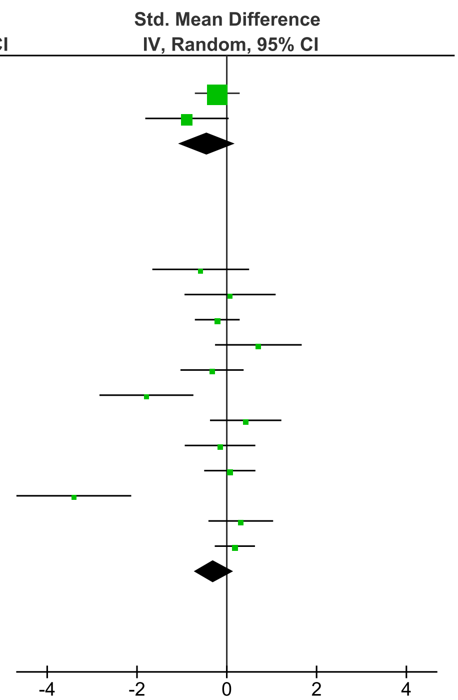


Fig 27. Short- and medium-term effects of resistance exercise training on c-reactive protein levels as standardised mean difference and 95% CI.